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Aeronautical Engineering REVIEW

March, 1956

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I.A.S. News Notes

March 1956

WILLIAM R. HAWTHORNE, MIAS, the first Hunsaker Professor of Aeronautical Engineering at Massachusetts Institute of Technology, will deliver the first Minta Martin Lecture before IAS meetings in four centers of aeronautical activity. His paper is entitled "The Aerodynamics of Aircraft Engines." Professor Hawthorne will speak March 21 at University of Maryland, with Baltimore, Washington, and Hagerstown members in attendance. On March 22 the Boston Section will hear him at M.I.T. The March 26 lecture will be held in the IAS Building, Los Angeles, with California Institute of Technology participating. The Cleveland-Akron Section will meet at Case Institute of Technology April 11 for the final lecture.

THE ANNUAL ELECTRONICS ISSUE of the Review will be published in May. Twelve of the electronics papers delivered at the Annual Meeting will be published in full, in addition to several special articles written specifically for this issue.

NATIONAL MEETINGS CALENDAR

March 9 Flight Propulsion Meeting (Confidential), Hotel Carter, Cleveland.
June 18-21 Summer Meeting, IAS Building, Los Angeles, California.
Aug. 15-17 Turbine-Powered Air Transportation Meeting, Grant Hotel, San Diego, California.

JOINT MEETINGS CALENDAR

Mar. 14-16 ASME -ARS -IAS Conference on Air Cargo & Air Logistics and Thermal Barrier, Hotel Statler, Los Angeles.
May 14-16 IRE National Conference on Aeronautical Electronics, Biltmore Hotel, Dayton. IAS Session on Human Engineering.
June 21-23 Heat Transfer and Fluid Mechanics Institute, Stanford University, Stanford, California.
Aug. 20-21 National Telemetering Conference, Biltmore Hotel, Los Angeles, Co-sponsored with AIEE, IRE, and ISA.

REGIONAL STUDENT CONFERENCES

March 12 Indianapolis Section Conference, Purdue University, Lafayette, Ind.
Apr. 13-14 Middle Atlantic Conf., University of Maryland, College Park, Md.
Apr. 19-21 Southwestern Conference, Hotel Adolphus, Dallas, Texas. Sponsored by the Texas Section.
Apr. 20-21 Northeastern Conference, Brown University, Providence, R. I.
Apr. 25 St. Louis Section Conference, St. Louis, Missouri.
Apr. 26-27 Southeastern Conference, Georgia Institute of Technology, Atlanta. Sponsored by the Atlanta Section.
May 3-5 West Coast Conference, IAS Building, Los Angeles. Sponsored by the Los Angeles Section.
May (open) Detroit Section Conference, Detroit, Michigan.

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

Mar. 9 Cleveland-Akron Section: Hotel Carter. Reception 6 p.m., Dinner 7 p.m. Address by C. C. Furnas, Asst. Secretary Defense (R&D).

Mar. 12 Indianapolis Section: Purdue University. "The Turbojet Engine--Its Potentialities and Problems for Supersonic Flight" by M. J. Zucrow.

Mar. 13 Los Angeles Section: Specialist Meeting at IAS Building, 8 p.m. "Electron Distribution in a Strong Shock Front" by J. W. Bond, Jr., General Electric Company.

Mar. 14 Niagara Frontier Section: Cornell Aeronautical Lab., 8 p.m. "VTO Transport Aircraft" by James A. O'Malley, Jr., Bell Aircraft Corp.

Mar. 15 Dayton Section: Van Cleve Hotel, 6:30 p.m. "Some High-Speed Turbojet Installation Problems" by David S. Gabriel, NACA.

Mar. 15 Los Angeles Section: IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "The Lockheed Electra" by Philip A. Colman, Chief Preliminary Design Engineer, Lockheed Aircraft Corporation.

Mar. 16 Los Angeles Section: Historical Meeting at IAS Building, 8 p.m.

Mar. 20 Columbus Section: Officers Club, Naval Air Station, 8:30 p.m. "Materials and Fabrication for High-Temperature Design" by Samuel A. Gordon, Battelle Memorial Institute.

Mar. 21 Washington Section: Minta Martin Lecture, University of Maryland. Inspection of aeronautical facilities 5:30 p.m., Dinner 6:30 p.m., Meeting 8 p.m. "The Aerodynamics of Aircraft Engines" by William R. Hawthorne, M.I.T.

Mar. 22 Los Angeles Section: Field Trip. Carrier cruise aboard U.S.S. Wasp. Reservations and clearance required.

Mar. 22 New York Section: "Training Problems for Space Flight" by Gordon Vaeth, Navy Special Devices Center. Place to be announced.

Mar. 22 San Diego Section: IAS Building. Reception 6:30 p.m., Dinner 7 p.m. "Operations Research as Applied to Engineering Problems" by R. F. Mettler, Ramo-Wooldridge Corporation.

Mar. 22 San Francisco Section: Ramor Oaks Restaurant, Atherton. Dinner 7 p.m., Meeting 8 p.m. "The Lockheed Electra" by Philip A. Colman, Chief Preliminary Design Engineer, Lockheed Aircraft Corp.

Mar. 23 Los Angeles Section: Trip to Aerojet-General Corp. (Confidential).

Mar. 23 St. Louis Section: Congress Hotel, 8 p.m. Confidential talk by Lt. Col. C. J. Butcher, Air Defense Command, USAF.

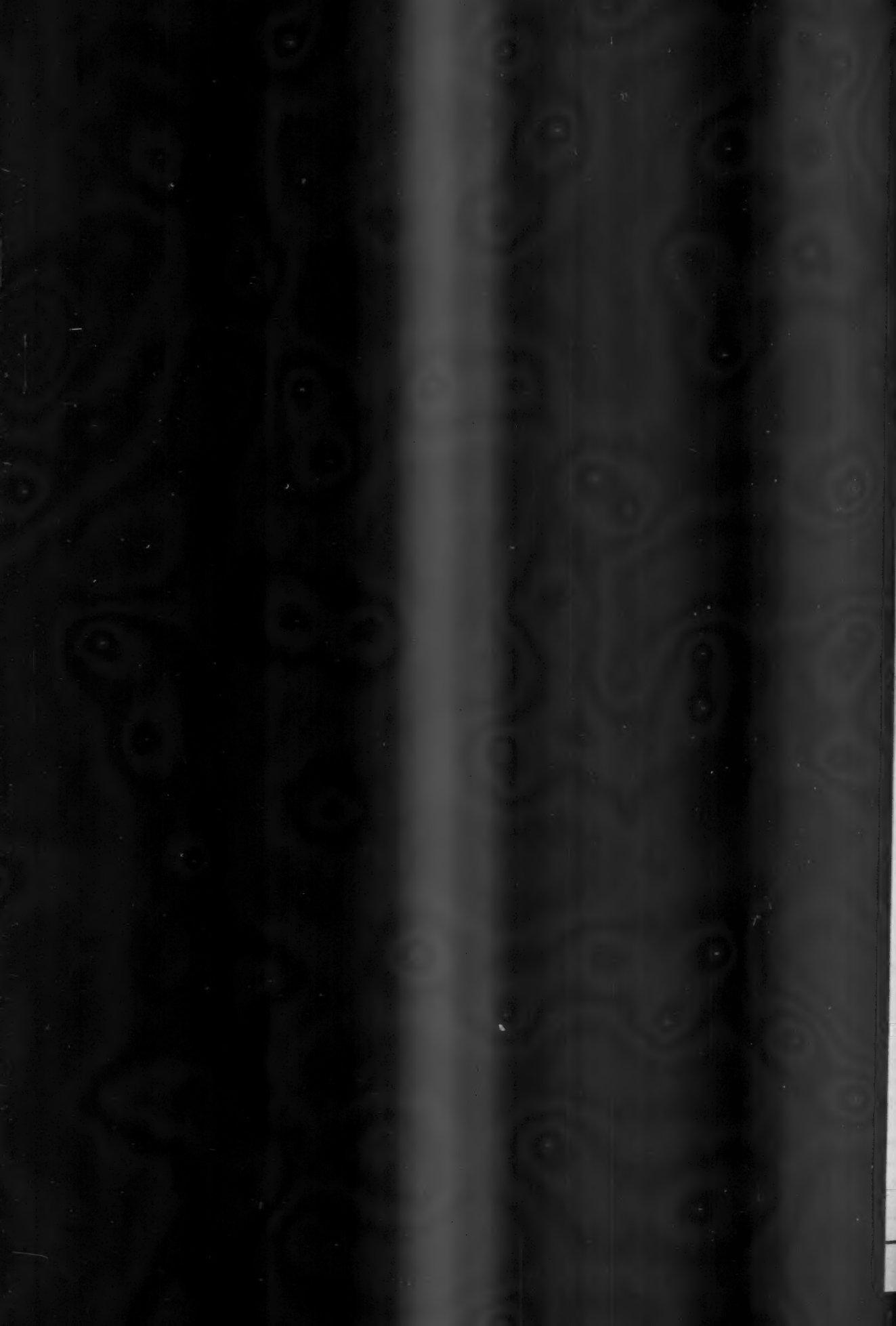
Mar. 26 Baltimore Section: Joint Meeting with ASME at Engineers' Club, 6:30 p.m. "The Vanguard Satellite."

Mar. 26 Los Angeles Section: Minta Martin Lecture, IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "The Aerodynamics of Aircraft Engines" by William R. Hawthorne, M.I.T.

Apr. 7 Los Angeles Section: Family Night, IAS Building. Buffet Dinner 7 p.m. Walt Disney movie, "History of Aviation," and talks.

Apr. 11 Cleveland-Akron Section: Case Institute of Technology. "The Aerodynamics of Aircraft Engines" by William R. Hawthorne, M.I.T.

Apr. 17 Columbus Section: Officers Club, Naval Air Station, 8:30 p.m. "Aeroelasticity at High Temperatures" by Robert Laidlaw, North American Aviation, Inc.



IAS News

A Record of People and Events of Interest to Institute Members

Annual Business Meeting of the Institute

Reports of President, Treasurer, and Director

THE TWENTY-FOURTH ANNUAL MEETING of the members of the Institute was held at the Hotel Sheraton-Astor, New York, on January 25, 1956. E. R. Sharp, President for 1956, presided.

Elmer A. Sperry, Jr., Teller, reported that he had received and counted 1,267 valid proxies for voting at the Annual Meeting—a quorum of the voting membership.

The Secretary reported that P. R. Bassett, Chairman of the Nominating Committee, was unable to attend the meeting and that he had requested that the following members be placed in nomination for election to vacancies on the Council:

Edward R. Sharp, Robert E. Gross, William B. Bergen, Victor E. Carbonara, Raymond C. Sebold, Edgar Schmued, Sherman M. Fairchild, and Kendall Perkins, for a term of 1 year each; Edward H. Heinemann, Raymond P. Lansing, Mundy I. Peale, Raymond H. Rice, and Charles Tilgner, Jr., for a term of 3 years each; and the following area councilors for a term of 1 year each: Eastern Area—Joel M. Jacobson and Jean A. Roche; Central Area—George J. McTigue and I. Nevin Palley; Western Area—J. E. Barfoot and Herman L. Braasch. On motion duly made, seconded, and carried, they were unanimously elected. The following were nominated and elected in like manner to serve on the Nominating Committee for 1956: L. B. Richardson, Chairman; J. L. Atwood, C. H. Colvin, H. L. Dryden, R. P. Harrington, H. L. Hibbard, C. J. McCarthy, and P. B. Taylor.

The Annual Reports of the President, Treasurer, and Director were read and approved. (See the following pages for the complete reports.)

The Secretary presented a list of honors conferred by the Institute in 1955 as follows:

The Thurman H. Bane Award to Gottfried Guderley, Chief Scientist, System Dynamics Research Branch, Aeronautical Research Laboratory, Wright Air Development Center, Ohio; The Octave Chanute Award to Major Gen. Albert Boyd, USAF, Commander, WADC (now Deputy Commander for Weapon Systems, Air Research and Development Command); The John Jeffries Award to Capt. Wilbur E. Kellum, USN (MC), Commander, Naval Medical Research Institute, Bethesda, Md.; the Robert M. Losey Award to Lt. Col. Robert C. Bundgaard, Commander, Air Weather Service, MacDill AFB, Fla.; The Sylvanus Albert Reed Award to H. Julian Allen, Chief, High-Speed Research Division, Ames Aeronautical Laboratory, NACA; The Lawrence Sperry Award to Giles J. Strickroth, Chief of the Electronics Division, The Glenn L. Martin Company; and the Wright Brothers Lecturer, R. L. Bisplinghoff, who spoke on "Some Structural and Aeroelastic Considerations of High-Speed Flight."

Honorary Fellowships in the Institute to: American—Ralph S. Damon, President, Trans World Airlines, Inc. (posthumously); Foreign—Peter G. Masefield, Managing Director, Bristol Aircraft Co., Subsidiary of The Bristol Aeroplane Co., Limited.

Fellowships in the Institute to: William B. Bergen, Executive Vice-President, The Glenn L. Martin Company; Lars Brising, Vice-President, Aeronautical Engineering, Saab Aircraft Company, Sweden; Victor E. Carbonara, President, Kollsman Instrument Corporation; Harold Luskin, Assistant Chief of Aerodynamics, Santa Monica Division, Douglas Aircraft Company, Inc.; G. N. Patterson, Director, Institute of Aerophysics, University of Toronto, Canada; Kendall Perkins, Vice-President—Engineering, McDonnell Aircraft Corporation; Raymond H. Rice, Vice-President and Chief Engineer, North American Aviation, Inc.; Lewis A. Rodert, Assistant to Chief of Research, Lewis Flight Propulsion Laboratory, NACA; Rear Adm. J. S. Russell, USN, Chief, Bureau of Aeronautics, Department of the Navy; Herman Schlichting, Professor, Technical University of Braunschweig, Germany.

The Secretary announced that the Council had elected the following officers of the Institute for 1956: President, Edward R. Sharp; Vice-Presidents, William B. Bergen, Victor E. Carbonara, Raymond C. Sebold, and Edgar Schmued; Director, S. Paul Johnston; Treasurer, Sherman M. Fairchild; Secretary, Robert R. Dexter; and Controller, Joseph J. Maitan.

ROBERT R. DEXTER
Secretary

President's Report—1955

ALTHOUGH THE activities of the Institute of the Aeronautical Sciences continued to expand in all areas of its operations during 1955 (as will be seen from the Director's Report which follows) and although we are glad to be able to report once again that the organization has wound up another year's operations in the black (see Treasurer's Report, p. 36), it seems to me that the most significant trend of the past year has been the strengthening of our position in the international picture.

It was my privilege to be the official host to the British delegation that came to Los Angeles in June for the Fifth International Conference with the Royal Aeronautical Society of Great Britain. The technical side of the Conference was excellent and proved once again the

value of interchange of engineering and scientific information, but to me the principal benefit of the meeting arose from personal contacts with our friends from overseas. Our close association with them during the weeks they were here led to a better understanding of problems on both sides of the Atlantic. The friendly interchange that began at the Conference will continue and will help strengthen the bond that exists between the two great English-speaking nations in the common defense of common ideals.

During 1955 also the IAS continued its collaboration with our opposite numbers in Canada through joint action with the newly formed Canadian Aeronautical Institute. By common consent, both the IAS and the RAeS have withdrawn their direct activities in Canada and are providing support and encouragement to the new organization. It is anticipated that, before many years, the CAI will participate as a full partner in future aeronautical conferences. Meanwhile, we of the IAS have been working with them on a bilateral basis. Our second joint meeting took place in Ottawa in November and was eminently successful.

We are continuing to explore other channels for international action. Our staff has been collaborating with AGARD (NATO's Advisory Group for Aeronautical Research and Development) by participating in appropriate committee and panel discussions. We were represented at the General Assembly in Ottawa in June and have been particularly active in the field of documentation and international interchange.

Out of this latter have emerged indications of a need for an improved technical abstracting service on an international scale. After some months of study and with financial support from the Air Research and Development Command, USAF, an expanded and accelerated abstract service has been started. The first edition appeared in the AERONAUTICAL ENGINEERING REVIEW in January, 1956.

We are very much aware of the growing stature of the Institute and are constantly alert to search out and exploit every opportunity to strengthen our position on an international basis.

On the domestic front, continuing progress has been made in strengthening our Sections and Branches. Several new Sections have been organized, and the support of our Student Branches has been augmented. In the latter area, we are greatly indebted to a Past President and Benefactor of the IAS, the late Glenn L. Martin. Two years ago he established the Minta Martin Aeronautical Student Fund with a gift of $250,000. At his death, under the terms of his will, he added an equal amount, making the Fund one of the largest in any scientific society for the direct support of aeronautical engineering education. This guarantees IAS participation in this important field for the indefinite future.

During the year also the Gabriel M. Giannini Film Library was active, both in the acquisition of additional films and in the distribution of films to our Branches and Sections.

Two appointments were made in 1955 to the Institute's Flight Test Engineering Fellowships at Princeton University. Applications for 1956 appointments have been solicited, and appointments will be made in the spring of 1956.

An examination of the Treasurer's Report will indicate that we have ended this year in a sound financial position. Our income has exceeded our expenditures, and your Council has made a distribution to our several reserve funds to ensure our future operations. Work has continued under our equipment maintenance and modernization policy to ensure that all our facilities are kept continuously in shape to serve the needs of our membership.

ROBERT E. GROSS
President, 1955

Treasurer's Report—1955

THE IAS COMPLETED its fiscal year in the black by the utilization of new systems, machines, and methods; the judicious control of expenditures; the splendid efforts of all Section officers in keeping local expenses to a minimum; and the continuing productivity of a high-morale staff.

Basically the IAS performs service functions, and accordingly its most significant cost is represented by salaries which, with the printing costs of its technical publications, represent about 75 per cent of total expenditures. As with all similar organizations, costs are immediately reflected, without compensatory adjustments of income. The general operations were continued at a higher level than in any previous year.

The income of the JOURNAL OF THE AERONAUTICAL SCIENCES was increased by $2,600 and that of the AERONAUTICAL ENGINEERING REVIEW by $12,300 over 1953–1954, but printing and editorial costs for both jumped $32,600 or a net cost increase of $17,700. The AERONAUTICAL ENGINEERING CATALOG met budget expectations, as did the Library and Archives operations.

International, national, Section, and student meetings—including reserves and special funds—totaled about 20 per cent of the gross expense of the IAS.

During the year, $5,000 of the $6,000 Reserve for Equipment Modernization was spent for new printing and accessory equipment. In addition, $3,500 was spent from the Building Alterations Reserve in combining several departments to provide a more efficient work flow pattern.

The contract of the Film Catalog—an operation housed in the IAS San Diego Building—has been extended by the Government for an additional 9 months. The net operations of the San Diego Building were slightly under break-even. Were it not for the excellent and time-consuming efforts of San Diego Section officers, the financial burden of the local building would have been much greater. The Los Angeles Building completed the year as a break-even operation.

There were no significant variations in the IAS Balance Sheet when compared to the previous year.

Your Finance Committee, together with representatives of the Investment Service Department of the Chase Manhattan Bank, periodically review the holdings in the portfolio and recommend changes based on current and anticipated conditions. The market value of the Institute's portfolio at September 30, 1955, was $382,971.96 in excess of its original value of $1,344,125.67.

A conservative budget for 1955–1956 has been presented to, and approved by, the Council. It is anticipated that the operations for the forthcoming year will be generally of the same magnitude as in 1954–1955.

The books of the Institute were audited in New York, Los Angeles and San Diego by Harris, Kerr, Forster & Company. A copy of their complete report is available to members at the national office.

CHARLES H. COLVIN
Treasurer

Director's Report—1955

THE PRESIDENT'S REPORT has stressed some of the broader international aspects of our program of the past year, and the Treasurer has reported on our current fiscal position. Following are outlined the pertinent

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Statement for the Fiscal Year October 1, 1954, to September 30, 1955

Consolidated Balance Sheet and Operating Statement

ASSETS

Unrestricted:		
Cash on Deposit	$ 50,667.03	
Accounts Receivable	55,804.22	
Advances on Intrafund Accounts	35,561.35	
Deposits and Prepayments	15,779.05	
Investments	825,756.50	
Furniture and Fixtures	5,000.00	
Total Unrestricted Assets		$988,568.15
Restricted:		
The Sherman M. Fairchild Fund	$ 11,248.51	
The G. M. Giannini Fund	3,896.39	
The Paul Kollsman Fund	69,000.00	
The Vernon Lynch Award Fund	39,189.72	
The Minta Martin Aeronautical Student Fund	261,020.45	
The Sylvanus Albert Reed Award Fund	13,661.90	
The Lawrence Sperry Award Fund	13,570.00	
Los Angeles Building Operating Fund	20,597.33	
New York Building Contingency Fund	104,525.24	
Pacific Aeronautical Library Fund	24,149.40	
San Diego Building Operating Fund	9,493.32	
Total Restricted Assets		$570,352.26
Facilities (at cost):		
Los Angeles	$427,640.20	
New York	220,415.26	
San Diego (land leasehold)	176,706.11	
Total Facilities		$824,761.57

LIABILITIES AND RESERVES

Unrestricted Funds:		
Accounts Payable and Deposits	$ 64,088.82	
Deferred Credits to Income	108,139.20	
Deferred Income—San Diego Building	15,842.77	
Deposit from Pacific Aeronautical Library	12,000.00	
Reserves	237,137.09	
General Fund—Balance September 30, 1955	551,360.27	
Total		$988,568.15
Restricted Funds (see Assets)		$570,352.26
Buildings, Land, and Equipment (see Assets)		$824,761.57

Statement of Income & Expenses

Income:		
Advertising Revenue	$333,833.63	
Dues and Entrance Fees	245,540.11	
Subscriptions	76,721.88	
Investments (unrestricted)	30,399.00	
Miscellaneous	9,933.63	
Total Income		$696,428.25
Expenses:		
Publications	$357,350.45	
Salaries	156,036.81	
Meetings and Travel, including Conference Reserve	38,529.93	
Employees' Retirement Fund, Reserve & Social Security	38,241.58	
Libraries	32,912.22	
Building Maintenance and Reserve for Repairs	23,155.99	
Printing, Postage, Telephone, Telegraph, Equipment	15,310.43	
Office Supplies and Expense, Insurance	12,213.46	
West Coast Offices (net)	8,975.90	
Miscellaneous	6,976.20	
Total Expense		$689,702.97
Net to General Fund		$ 6,725.28

facts and figures relating to the general activities of the Institute.

Membership

Again, without any pressure from national campaigns, the steady growth that has marked our membership trend over the past year has continued. The net gain in graded members for this year was nearly 700 (as will be seen from Table 1), in spite of the elimination of about 100 former Historical Associates. (This grade was dropped by action of the Council.) The improvement in Section activities, both in quantity and quality, accounts for much of the gain.

Section Activities

As can be seen from Table 2, all aspects of Section activities reached new highs for 1955. This marks the tenth consecutive year during which new highs in every category were achieved; the single exception was the voluntary transfer of three Canadian Sections to the CAI in 1954.

The two most important improvements during 1955 were the establishment of three new Sections—(Tulsa, San Antonio, and Rocky Mountain)—bringing the total to 27, and the announcement of new sponsorship by Sections of two of the 1956 Student Paper Competitions (Atlanta Section has assumed sponsorship of the existing Southeastern Conference, and Indianapolis Section has started its own). Now that all but two (Northeastern Conference and the newly formed Middle-Atlantic Conference) of the eight Student Conferences are under Section management, our original goal of overall Section coverage is near realization. Other highlights are outlined in the following paragraphs.

The increase in Section membership was almost 600. Outstanding among Section Membership Committees is St. Louis, which in 1955 produced well over 200 membership applications, equivalent to 100 per cent of the membership of the Section.

The number of Section meetings increased by 10 per cent over last year, from 241 to 267. This total is equivalent to an average of 10 meetings per Section.

TABLE 1
Membership Breakdown—Comparisons by Calendar Year
(January 11, 1956)

	12/31/53	*12/31/54*	*12/31/55*
Temporary Honorary Members	15	16	16
Honorary Fellows	28	30	32
Fellows	197	199	198
Associate Fellows	757	829	926
MEMBERS	3,878	4,212	4,668
Associate Members	440	482	502
Historical Associate Members	74	102	...
Technical Members	4,329	4,410	4,633
Total Graded	9,718	10,280	10,975
Student Members	2,672	3,110	2,984
Total	12,390	13,390	13,959

Five issues of the Section Chairmen's *Newsletter* were published in 1955. The October issue marked the second anniversary of this publication. The San Diego and St. Louis Sections published their own newsletters to their members. We are distributing these to all Section Chairmen as issued.

A Guide for Section Officers was published in October, 1955, containing IAS procedures and ideas helpful in Section operation. Initial distribution was 100 copies.

Two meetings of Section Chairmen were held in 1955, one during the Annual Meeting in New York and one during the Annual Summer Meeting in Los Angeles.

Virtually all Sections now have active Student Activities Committees. In all cases, these committees have attracted enthusiastic people.

Student Activities

In addition to the growth figures given for Student Branches in Table 2, the following reflects the increased emphasis placed by the IAS on its student activities during 1955. These are first steps toward a broadening program.

During 1955, 7,051 copies of the *IAS Vocational Guidance Manual, A Guide to the Engineering Professions in the Aviation Industries* (January, 1954) were distributed to schools, libraries, and guidance counselors and to groups, Sections, Branches, and individual students.

During the latter part of the year, preliminary work was started to produce a new IAS publication, a booklet which will present to high school students and their parents an accurate, understandable picture of aeronautical engineering as a career. Estimated publication date is Spring, 1956.

A revision of the *IAS Student Membership Folder*, describing the benefits and privileges of IAS membership, was published in 1955. Six thousand of these folders were distributed to colleges and universities.

In April of 1955, announcement was made of the award of two IAS Fellowships in Flight-Test Engineering at Princeton University. These 2-year Fellowships are provided by an anonymous donor and administered by the IAS. Announcements and applications for the 1956 award have been published and distributed.

In the spring of 1955, six IAS Regional Student Conferences were held, one each in Detroit, New York, St. Louis, Dallas, Los Angeles, and Atlanta. Two newly proposed Conferences will take place in 1956—one, the "Middle-Atlantic," to be held at the University of Maryland, the other at Indianapolis.

Nine technical papers that each won first prize in the 1955 Conferences were published in an 88-page booklet *1955 First Award Papers*, 700 copies of which have been distributed to Sections and Branches and to schools, libraries, and individuals.

Two national awards—one graduate, one undergraduate—have been established. The winners have been selected from those First Award Papers published, and the prizes—engraved plaques—will be presented in early 1956.

A completely revised *Student Branch Manual* was published in 1955. This 22-page booklet incorporates current

TABLE 2
Annual Report—Sections and Branches
(January 1, 1956)

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Sections	13	17	19	19	23	24	25	26	24	27
Section Meetings	72	92	121	126	144	168	181	237	241	267
Section Members	4,166	4,734	5,032	5,718	6,436	7,143	7,379	8,408	8,411	8,999
Branches	38	51	60	67	70	71	71	69	71	73
Branch Meetings	210	277	327	336	317	323	350	319	366	400*
Student Members	1,655	3,300	4,068	3,958	3,395	3,006	2,796	2,672	3,110	2,984

* Estimated.

procedures for the establishment and function of the Student Branch, outlines the benefits of Student Membership, and includes a copy of the "Rules and By-Laws" for IAS Student Branches; 325 copies have been distributed to Sections, Branches, and interested individuals.

The second edition of the *IAS Thesis Topics List* was published in 1955. This 131-page booklet lists over 700 topics suggested by Corporate Members and offers the student the names and addresses of persons who may be contacted for further information about each topic. Six hundred and fifty copies of this publication have been distributed to Corporate Members, Sections, Branches, and interested individuals.

In January, 1955, an 8-page booklet *A Source Listing of Selected Aeronautical Films* was published. This booklet listed 106 films and was distributed to all Sections and Branches. In September, 1955, a revised edition was published, entitled *The Giannini Film List*. This 22-page source catalog listed 168 unclassified, released aeronautical films, all 16 mm. and available on a loan basis. Nine hundred and fifty copies of the list have been distributed to Corporate Members, Members, Sections and Branches, and to interested individuals. Efforts have been made to increase the size of the Film Library and the efficiency of the automatic film distribution system.

Meetings

IAS meetings at all levels maintained a high standard of quality. Section meetings showed noticeable improvement in this regard. An increasing number of papers presented at Section meetings meet national meeting standards. Many of them eventually reach publication.

This year was marked by an increased number of cooperative meetings with other societies. It is present policy to collaborate with other technical groups at all levels as the Twenty-Fourth Annual Meeting program indicates. Many other examples can be found in the following outline of the 1955 meeting program.

National Meetings

Jan. 24–28	Twenty-Third Annual Meeting, New York
Mar. 11	Tenth Annual Flight Propulsion Meeting, Cleveland
June 20–23	Fifth International Aeronautical Conference—RAeS-IAS, Los Angeles
Aug. 8–10	Second Turbine-Powered Air Transportation Meeting, Seattle, including tour of Boeing Flight Test Center
Dec. 17	Nineteenth Wright Brothers Lecture, Washington, D.C. Lecture repeated in Seattle, Dec. 19; Los Angeles, Dec. 20; and Cleveland, Dec. 22

Joint and Participating Meetings

May 9–11	IRE-IAS National Conference on Aeronautical Electronics, Dayton, Ohio
May 18–20	IRE, AIEE, ISA, and IAS National Telemetering Conference, Chicago
June 23–25	Heat Transfer and Fluid Mechanics Institute, U.C.L.A., Los Angeles
Sept. 8–10	Midwestern Conference on Solid Mechanics and Fluid Mechanics, Purdue University
Oct. 7	Symposium on Escape from High Performance Aircraft (Institute of Transportation & Traffic Engrg. & Engrg. Extension, U.C.L.A.; the Aeromedical-Engineering Association; and IAS, Los Angeles)
Nov. 3–4	CAI-IAS Second Annual Joint Meeting, Ottawa, Canada
Nov. 14	ASME-IAS Air Cargo and Heavy Press Sessions, Chicago
Dec. 12–16	Nuclear Engineering and Science Congress, Cleveland (Engineers Joint Council)

Military Tours and Visits

May 24–25	IAS visit to NADMC, Johnsville, Pa., and NATTS, Trenton, N.J.
June 23	USAF Contractor Flight Test Center, Palmdale, Calif.
Nov. 9–10	IAS Day—WADC, Wright-Patterson AFB, Ohio

Publications

As announced in the December issue of the REVIEW and the January issue of the JOURNAL, the editorship of the latter publication changed hands in January, 1956. Dr. Hugh Dryden, who had directed the editorial policy of the JOURNAL for many years, had asked to be relieved and was replaced by Dr. William Sears of Cornell. Dr. Sears had been active on JOURNAL committees for many years.

Beginning in January, 1956, the editorial content of the JOURNAL has been increased from an average of 72 pages per issue to 96. This will provide better technical coverage and will reduce the backlog of excellent papers which has accumulated during the year.

As will be noted in the Treasurer's Report, the REVIEW had another successful year. Its editorial content and format have been under continuous study and improvement. Its editors have been guided by the requirements of its readers as disclosed in surveys and from direct comments received from readers. New services have been added, notably the new International Aeronautical Abstracts section which appeared for the first time in the January, 1956, issue. This project is supported by a contract with the Air Research and Development Command, USAF.

In spite of continually increasing production costs (we have had a 40 per cent increase in printing and engraving costs over the past 5 years), advertising income has been developed to keep the publication well in the black. The high quality of the magazine has been reflected in increasing advertising acceptance in a highly competitive market.

The CATALOG, also in a highly competitive position, compared favorably with preceding issues. Its usefulness was improved by a complete editorial revision last year.

An innovation which appeared to be acceptable to our membership, as well as profitable financially in the overall, was the combination of the ROSTER with the September issue of the REVIEW. This arrangement will be continued.

Library and Special Services

IAS Libraries on both East and West Coasts have continued to improve their usefulness to our members. Nell Steinmetz and her able staff at Pacific Aeronautical Library, Los Angeles, are maintaining the high standard of service established many years ago in keeping the Western elements of the industry up to date on the technical information they need.

At San Diego a restudy is under way of library requirements there. Most notable activity at that facility, however, is the Film Cataloging Unit operating under Roy Elliott under an ARDC contract. The first year's work proved extremely satisfactory to the Air Force, and our contract was renewed for the second year. Periodic progress reports are submitted, both to the Air Force and to IAS Headquarters.

The Library in New York has undergone considerable revision during 1955. Reworking and cataloging the collec-

tions with a view toward improving their usefulness to our members has continued. Many unneeded duplications and much "dead-wood" have been eliminated. With the approval of the Council and the original donors, much unused material of a nontechnical or historical nature has been turned over to other libraries where demand for such material exists. These include the Harvard Business School Library and the Smithsonian and Congressional libraries in Washington.

Although, as mentioned above, the grade of Historical Associate Member in the Institute has been eliminated, interest in historical matters has not been dropped. A new historical activity is in operation under which periodic meetings on historical subjects are held, both in Los Angeles and in New York, and under which AERONAUTICA will be continued.

Facilities

The program of modernizing our equipment has been continued. At the Los Angeles facility the air conditioning and improved kitchen equipment paid off during the Fifth International Conference in June. The New York printing plant modernization authorized by the Council in 1954 was completed and is in satisfactory operation. By concentrating all storage, trimming, printing, addressing, and mailing facilities in one area in the basement of the building, considerable improvement in service to our Sections and an appreciable saving in cost have resulted.

General

The satisfactory results that show up in the Treasurer's Report with reference to the operation of our two Western Region facilities are due to the hard work and good management of the IAS Sections in the area, under the general supervision of our able Western Region Manager, E. W. Robischon.

I would like to take the opportunity to extend my personal thanks and appreciation to all members of the staff whose day-to-day interest and loyalty to the Institute make our work possible. Our collective thanks, also, to the Officers and Council who provide support and policy direction—and to every member of the IAS who has participated in any degree in our activities at all levels.

S. PAUL JOHNSTON
Director

First Minta Martin Student Awards Are Presented

Six Regional Student Conferences were conducted by the IAS during the past year under auspices of the Minta Martin Aeronautical Student Fund, giving engineering students a taste of competition in presenting original papers before an audience.

From among more than 75 technical papers written and delivered in person by college students, nine that won top awards in 1955 have been published as a bound volume by the Institute. Two of these were subsequently chosen as national winners, and their authors received a new award which was presented for the first time at the IAS Honors Night Dinner in New York.

Only one winner, Voigt R. Hodgson, of Roseville, Mich., was able to attend the dinner. He received his plaque and certificate from Robert E. Gross, 1955 President of the IAS, who is President and Board Chairman of Lockheed Aircraft Corporation. The other winner was David L. Cochran, of Genoa, Nev., a graduate student at Stanford University. His award was to be presented on some appropriate occasion more convenient geographically.

Mr. Hodgson, who was graduated from Wayne University last June with a B.S. in Aeronautical Engineering, was Chairman of the IAS Student Branch there during his senior year. He took the Minta Martin Aeronautica Student Fund National Award in the Undergraduate Division with a paper entitled, "Hydrofoils Applied to Sailcraft—A Problem in Aero- and Hydrodynamics."

Mr. Hodgson, incidentally, was President of the Wayne University Glider Club. He is fond of gliding, sailing, and skiing. He is now doing postgraduate work in engineering mechanics while employed as a Structures Test Engineer by the Ford Motor Company.

Voigt R. Hodgson

David L. Cochran

Before entering college, he served in the Navy during World War II and later worked as a telephone lineman.

Arthur A. Locke, AFIAS, Head of the Department of Aeronautical Engineering at Wayne University, assisted Mr. Hodgson in preparation of the manuscript.

Mr. Cochran was declared the national winner in the Graduate Division for his paper on "A Simple Means for Producing Efficient Wide-Angle Diffusers." A graduate of the University of Nevada, he received his Master's degree in Mechanical Engineering at Stanford in 1952 and is now working toward his Ph.D.

The Minta Martin Aeronautical Student Fund was established 2 years ago by the late Glenn L. Martin in honor of his mother, who encouraged him to build and fly his own airplane in 1909. The original endowment was $250,000, and Mr. Martin, who was a Past President of the IAS, directed in his will that an additional $250,000 be added to it. The Fund is administered by the Institute to encourage aeronautical engineering education. Its income finances regional student conferences, lectures, the publication of booklets, and the distribution of scientific information—all in relation to the advancement of aeronautics.

Admiral de Florez Heads Flight Safety Foundation

Rear Adm. Luis de Florez, USN (Ret.), FIAS, has been named President of the Flight Safety Foundation, Inc., of New York. He succeeds the late Adm. John H. Towers and will serve without compensation.

Admiral de Florez is a Director of de Florez & Company, Consulting Engineers. He learned to fly in 1912 and served with the Navy in both world wars. Specializing in the study of re-

(*Continued on page 85*)

Newly Elected Members of the Institute Council

Eastern Area (1-year term)

Joel M. Jacobson
Vice-Pres. & Gen. Mgr.
Aircraft Armaments, Inc.

Jean A. Roché
USAF Development Field Rep.
at Langley Aero. Lab., NACA

Central Area (1-year term)

G. J. McTigue
Manager
Aircraft Engine Sales
General Electric Co.

I. Nevin Palley
Vice-President
Engineering
Temco Aircraft Corp.

Western Area (1-year term)

Joseph E. Barfoot
Project Engineer
Boeing Airplane Co.

Herman L. Braasch
Chief, Aircraft Section
Ryan Aeronautical Co.

Council Members (3-year term)

Edward H. Heinemann
Chief Engr., El Segundo Div.
Douglas Aircraft Co., Inc.

Raymond P. Lansing
Vice-President
Bendix Aviation Corp.

(Bottom left)
Mundy I. Peale
President
Republic Aviation Corp.

(Bottom right)
Charles Tilgner, Jr.
Chief Aeronautical Engineer
Grumman Aircraft Engrg. Corp

Raymond H. Rice
Vice-Pres. & Chief Engr.
North American Aviation, Inc.

Vice-President
William B. Bergen
Executive Vice-President
The Glenn L. Martin Company

President
Edward R. Sharp
Director
Lewis Flight Propulsion Lab., NACA

Vice-President
Victor E. Carbonara
President
Kollsman Instrument Corporation

IAS Officers for 1956

Staff Officers for 1956

S. Paul Johnston, Director

Robert R. Dexter, Secretary

Joseph J. Maitan, Controller

Vice-President
Edgar Schmued
Vice-President
In Charge of Engineering
Northrop Aircraft, Inc.

Treasurer
Sherman M. Fairchild
Chairman of the Board
Fairchild Camera and Instrument Corporation

Vice-President
Raymond C. Sebold
Vice-President—Engineering
Convair, A Division
of General Dynamics Corporation

American Honorary Fellow
The late Ralph S. Damon

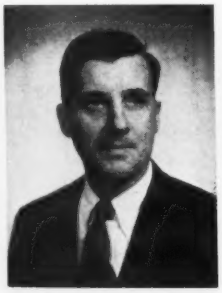
Honorary Fellows for 1955

Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. Not more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellow in any one year.

Foreign Honorary Fellow
Peter Gordon Masefield

Fellowships in the Institute—1955

Fellows of the Institute of the Aeronautical Sciences shall be those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering.



William B. Bergen
Executive Vice-President
The Glenn L. Martin Company

Lars Brising
Vice-President
Aeronautical Engineering
Saab Aircraft Company, Sweden

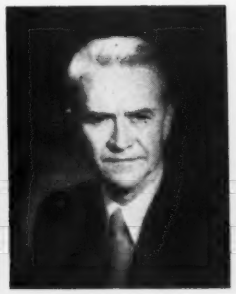
Victor E. Carbonara
President
Kollsman Instrument Corporation

Harold Luskin
Assistant Chief—Aerodynamics
Santa Monica Division
Douglas Aircraft Company Inc.

Gordon N. Patterson
Director
Institute of Aerophysics
University of Toronto

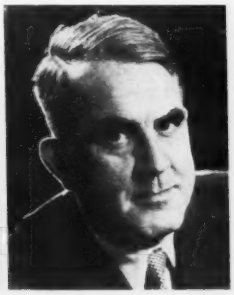
Kendall Perkins
Vice-President
Engineering
McDonnell Aircraft Corporation

Raymond H. Rice
Vice-President and
Chief Engineer
North American Aviation, Inc.



Lewis A. Rodert
Assistant to Chief of Research
Lewis Flight Propulsion
Laboratory, NACA

Rear Adm. James S. Russell
Chief
Bureau of Aeronautics
Department of the Navy



Hermann Schlichting
Professor
Technical University of
Braunschweig, Germany

IAS Awards and

Capt. Wilbur E. Kellum
Commander, Naval Medical Research Institute
National Naval Medical Center

The John Jeffries Award

This annual award honors the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous flight made the earliest recorded scientific observation from the air. This award, which has an honorarium of $200, was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine.

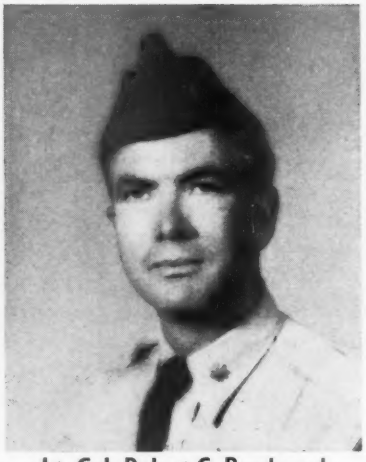
Presented to CAPT. WILBUR E. KELLUM, USN

"For outstanding contributions to the advancement of aeronautics through medical research."

Captain Wilbur E. Kellum is Commander of the Naval Medical Research Institute at the National Naval Medical Center, Bethesda, Md. Before assuming this post in 1951, after a year as Executive Officer, he was Flight Surgeon in charge of the Naval School of Aviation Medicine and Research, Pensacola, Fla.

Captain Kellum joined the Navy Medical Corps as an Assistant Surgeon in 1928. In 1933, he began studies in the psychological selection of candidates for flight training. A few years later, he pioneered in the design of oxygen equipment, developing one of the first oxygen masks to replace the old "pipe stem" on a tube. While holding administrative positions in the Navy Department during the years 1942 to 1945, Captain Kellum (1) sponsored and directed further studies in psychological selection of aviators; (2) conceived, developed, and directed the night-vision training program for Navy pilots and air crewmen; (3) planned and administered a nation-wide organization providing medical service for the aviation cadet training program; and (4) planned and administered the medical portion of the program for air evacuation of the wounded by the Navy.

A member of the Interim Board of Aviation Medicine for the past 5 years, Captain Kellum has done much to improve the training and qualifications of the Navy's Flight Surgeons. He was President of the Aero Medical Association in 1950.



Lt. Col. Robert C. Bundgaard
Chief, Evaluation and Development Branch
Air Weather Service, USAF

The Robert M. Losey Award

Established in 1940, this annual award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. This award carries an honorarium of $200.

Presented to LT. COL. ROBERT C. BUNDGAARD, USAF

"In recognition of outstanding contributions to the science of meteorology as applied to aeronautics."

Lieutenant Colonel Robert C. Bundgaard, who has been in charge of Project Black Sheep for the past 3 years, is Chief of the Evaluation and Development Branch, Directorate of Scientific Services, Headquarters, Air Weather Service, U.S. Air Force.

Project Black Sheep, located at McDill AFB, Tampa, Fla., is a weather research project for high-performance aircraft. Colonel Bundgaard was cited for developing and improving techniques for providing weather advice in the operation of military jet aircraft. He has demonstrated remarkable initiative in the evaluation and solution of high-level forecasting problems. He recently developed a method for more accurately analyzing and forecasting winds in the region of the tropopause. This region, where jet aircraft normally fly, is the most difficult for wind prediction because of complicating factors such as the jet stream.

The maximum-wind shear chart, envisioned by Colonel Bundgaard and developed under his guidance, represents a notable advance in the field of aviation meteorology. Use of this chart, with certain techniques previously developed, results for the first time in a logical, integrated, step-by-step procedure for predicting a minimal flight path in time and space. This procedure overcomes a host of difficulties previously encountered in determining such a path.. When applied to the slowly climbing jet profile, it makes possible a flight of either maximum range or minimum fuel consumption.

Honors for 1955

Harvey Julian Allen
Chief, High-Speed Research Division
Ames Aeronautical Laboratory, NACA

The Sylvanus Albert Reed Award

For a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics.

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award with a certificate and honorarium of $250. The recipient is chosen by ballot of the American Honorary Fellows and Fellows of the Institute.

Presented to H. JULIAN ALLEN

"For contributions and leadership in solving problems in the design of supersonic airplanes and missiles, especially the thermal problems at hypersonic speeds."

H. Julian Allen, Chief of the High-Speed Research Division of Ames Aeronautical Laboratory, has been with the National Advisory Committee for Aeronautics since 1936. He has become a recognized authority on the aerodynamics of intercontinental ballistic missiles and on the design of transonic, supersonic, and hypersonic wind tunnels and test facilities.

His research accomplishments include the development of a well-known theory for predicting forces at supersonic speeds on bodies at angles of attack, as well as contributions to the understanding of the flow about, and the oscillating vortex discharges from, such bodies; the experimental investigation of heat transfer and boundary-layer development at supersonic speeds; an understanding of flow on and behind wings and bodies in the presence of shock-wave boundary-layer interaction; and an understanding of the aerodynamics of flight at hypersonic speeds.

Mr. Allen has conceived and effectively applied a variety of new techniques and types of equipment for investigating supersonic and hypersonic aerodynamics. These include the supersonic free-flight wind tunnel; the sliding-block asymmetric wind-tunnel nozzle and the single-jack nozzle; the vapor screen technique for flow visualization; and the stroboscopic and self-synchronizing schlieren apparatus.

Giles J. Strickroth
Manager, Electronics Department
The Glenn L. Martin Company

The Lawrence Sperry Award

For a notable contribution made by a young man to the advancement of aeronautics.

This award was endowed in 1936 by the sister and brothers of the late Lawrence Burst Sperry, pioneer aviator and inventor, who was drowned in 1923, at the age of 31, when his plane developed motor trouble over the English Channel. The annual award consists of a certificate and an honorarium of $250.

Presented to GILES J. STRICKROTH

"For contributions to the development of the guidance system for the Martin Matador, the first and only tactical ground-to-ground missile to be put into operational use by the U.S. Air Force."

G. J. Strickroth, Manager of the Electronics Department of The Glenn L. Martin Company, is given major credit for development of the tactical guidance system of the TM-61 Matador. He served on the Matador project from 1946 to 1952 and was in charge of guidance system work from 1950 to 1952.

In addition to the guidance equipment, the essential elements of the system include a mathematical method for accurate firing and a method for calibrating highly mobile ground support equipment that can be operated in the field by relatively unskilled personnel.

Mr. Strickroth also was primarily responsible for the philosophy of unit construction, unit interchangeability, and unit testing on the Matador, which provides a highly flexible and wholly mobile missile weapons system in operation. Now 33 years old, he obtained his Electrical Engineering degree from Catholic University of America in 1943.

Entering the University with a scholarship in music, Mr. Strickroth distinguished himself as a tuba soloist and track star. After graduating, he worked 3 years as an electronics engineer with Friez Instrument Division of Bendix Aviation Corporation before joining Martin in 1946.

Editorial

IAS President • 1956

Edward R. Sharp

Director
Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics

EDWARD R. SHARP comes to the presidency of the Institute with a host of friends among its officers and members—and a wide working knowledge of its problems and activities. As a long-time member of the Council and as a Vice-President of the past year, he has taken an active interest in our operations and is familiar with our way of doing things.

Our association with Dr. Sharp's own organization, NACA, has been an intimate one for many years. We, as a Society, have benefited greatly through this collaboration, and, we hope, there have been corresponding gains to the other side. NACA personnel have figured prominently in IAS technical programs from the beginning, and our members have had many opportunities to visit NACA facilities under IAS auspices. Outstanding have been our meetings on engine, propeller, jet, and rocket propulsion problems held every spring in Cleveland for the past 10 years. Dr. Sharp and his staff have made these occasions not only memorable but possible.

It is not a new thing for those of us on the staff to work with "Ray." We are looking forward to a continuation on an even closer scale. We pledge him our full support and cooperation during the year of his presidency.

It should be a source of great satisfaction to all members of this organization that Robert E. Gross, who heads one of the largest elements of our industry—one of the most important links in the national defense chain—has been willing to devote a very appreciable part of his busy life to the affairs of the Institute.

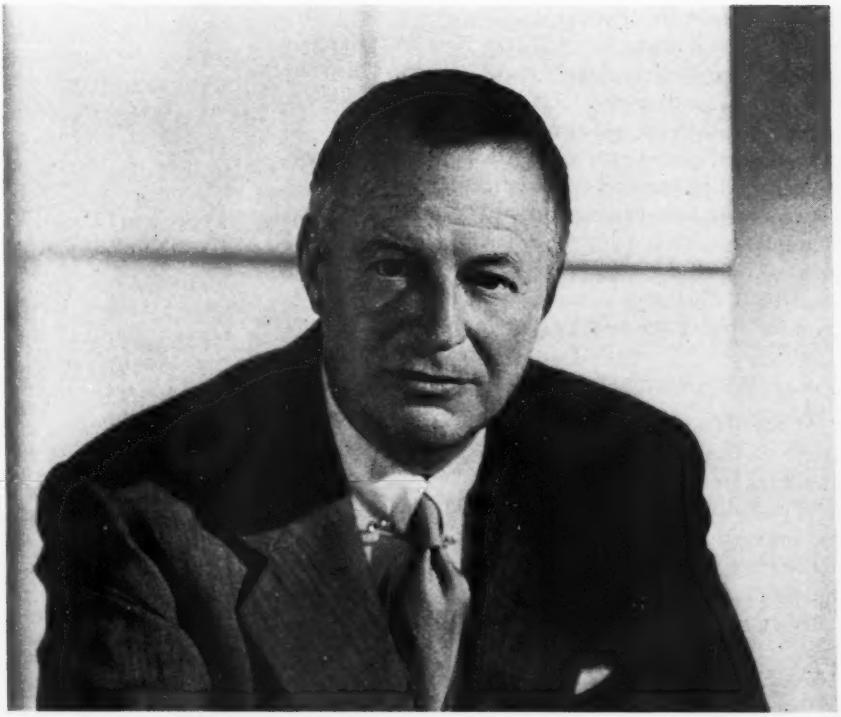
The job of IAS President in 1955 was no sinecure. For 2 weeks' time (in June) Bob Gross made himself available—as their host—to the British delegates to the Fifth International Conference. He not only performed the presidential functions at most of our meetings, but also he and Mrs. Gross carried more than their share of the entertainment load. Much of the success of the Conference came from his personal contributions.

Throughout the year we have had the benefit of Bob's interest and advice in the Council. He has been continuously informed of our progress and activities and has personally participated in many of them.

As he steps down from office he carries with him our thanks and appreciation for the job he has done. Since he is an ex-officio member of the Council during the coming year, we will continue to benefit from his interest and wise policy guidance.

S.P.J.

IAS President 1955



Robert E. Gross

President
Lockheed Aircraft Corporation

A discussion of the military advantages of a type of fixed-wing aircraft having normal cruise speeds and limited take-off and landing space requirements and of the devices that will make such aircraft possible.

STOL Airplanes—A New Approach to Air Transport

R. A. Darby*
Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation

Introduction

Now, or at any time, if we believe our papers and suspect the innate wickedness of mankind, our most important cities could be devastated by surprise nuclear attack. This paper gives consideration to a type of airplane which could aid immeasurably in the transportation problems of nuclear war.

This type, or types, of airplane can, for want of more inspired designation, be called Short Take-Off and Landing, or STOL, airplanes. By way of further definition, we may think of them as possessing the ability to clear a 50-ft obstacle in 500 ft. or less, in take-off or landing, and having about normal transport airplane cruise speed for their size. They will have a much wider speed range than present airplanes, say 10 or better. In some cases, they may approach vertical take-off and landing capabilities, but they will not be designed to fly on a vertical path, or hover, since great benefits are believed to result from their using some horizontal distance and forward velocity, and in general a limited space will be available. They will in some way use power directly from fuel during the landing process.

Historical Background

At the outset of any attempted development, it is interesting and helpful to search our memories and the literature for past efforts. Early airplanes, often flown from inside the small ovals of fairground trotting tracks, had impressively short take-offs and landings, inherent in their low wing loadings and high drag, but they were not STOL aircraft because they utterly lacked speed range and could use little or no power to shorten landings.

Until quite recently, design attempts consciously directed at STOL performance were few. None led to production, although most showed great promise. The first figures show four, beginning with the earliest to my knowledge. Purposely omitted are machines like the Curtiss Tanager which relied solely on slots and flaps for low-speed performance.

Fig. 1 shows the Crouch-Bolas Dragonfly I, flown in 1934 by the Crouch-Bolas Aircraft Corporation of Pawtucket, R.I. With 9-ft.-diameter, opposite-rotating propellers on fan-cooled, geared engines of 90 hp., this 2,100-lb., 26-ft.-span biplane was a true example of what will later be explained as "the vectored slipstream principle." Published data on the airplane give a ground run of 30 ft., an angle of climb of 50°, and an angle of descent of 70°. With nearly all of its wing area in the slipstream of its oversize propellers, the airplane made nose-high landings with considerable power on. It was this fact, that the airplane used power to land short, which occasioned the most frequent criticism of it from the convention-bound aviators of the time. The design was heartily attested to by professors at New York and Brown Universities, and the designer, Harold Bolas, now of the British firm of Saunders-Roe, Limited, made thorough static tests of the aerodynamics involved—tests which have lately been repeated. Another engineer of the Crouch-Bolas group has told me that the airplane substantiated the advertised performance and made many vertical ascents and descents in a moderate breeze.

The second airplane, Fig. 2, designed with the expectation of STOL performance was this obscure effort of

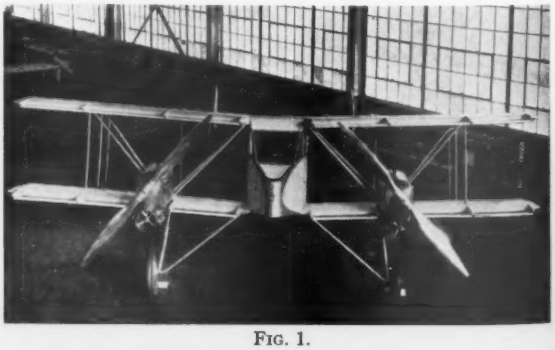


Fig. 1.

Presented before the IAS Washington Section, Nov. 8, 1955, and the IAS New York Section, Dec. 8, 1955.

* Chief Research and Development Engineer.

a German alien which was flown at Hadley Field, N.J., also in 1934. It had a system of full-span, blowing-slot boundary-layer control, with blowing slots over the elevators, in anticipation of extremely low minimum flying speeds. Say what you will, this airplane was a beautifully direct attempt to apply the findings of NACA Technical Report 385. It had all the elements of several recently proposed boundary-layer control schemes, including tail blowing and independent blowing power. A motorcycle engine was used to run the blowers. Costing less than $4,000—the engineers worked for stock—the airplane proved too crude to succeed and was never flown with the BLC operating.

In 1942 the highly unorthodox Vought V-173 Pancake, Fig. 3, was flown. The V-173 was a full-scale version, except for power, of the projected XF5U-1, a carrier-based Navy fighter design fully meriting the STOL designation. Extremely short take-offs and landings were demonstrated with the V-173. It was expected that the XF5U-1, powered by two R-2800 engines, would have a landing speed of 35 knots with a high speed of 370. It employed a wing of nearly circular plan form, mounting slender booms for the two extremely large-diameter, articulated propellers. Opposite rotation of the propellers, against the wing-tip vortices, was to abate induced drag. Engines were buried in the wing, were interconnected, and drove the propellers through shafts and gear boxes. A very long alighting gear gave the propeller axis a ground angle of about 30°. Hovering was to be accomplished by pulling the airplane up to a vertical attitude and hanging on the propellers. The XF5U-1 approached the VTOL concept and, if completed, would in many respects have antedated the recent XFY and XFV by more than 10 years. Happily, the guiding light on this project, Charles Zimmerman, is now at the NACA where he has instigated a greatly needed research program which, if sufficiently implemented, will go well beyond the concept of the XF5U-1.

The last example of early STOL airplanes is the Dow-Stalker BLC modification of the L-1, Fig. 4, made for the Army Air Force and flown in 1944. Professor Stalker, formerly of the University of Michigan, is noted for his studies of boundary-layer control during the 1930's. In this airplane he had a large change in camber, with separation control by two full-span suction slots. It is evident where the pumping apparatus was carried. Unfortunately, the airplane crashed,

FIG. 3.

killing its pilot, before significant data could be obtained. It was, however, a well-engineered attempt at bettering the speed ratio by putting power directly into the wing.

WHY STOL AIRPLANES ARE NOT IN SERVICE TODAY

You perhaps wonder why, 52 years after Kitty Hawk, there is still no such thing as a STOL airplane in service. The explanation is substantially this: For the last 30 years, if not since Beachey beat Oldfield in 1911, high speed has been the main objective in airplane design. It is the *sine qua non* for combat aircraft and for economical transport aircraft as well. For a given propulsion system and degree of cleanness, the high speed of an airplane can be increased only by raising its wing loading. Wing loadings have been pushed up, year by year. But in conventional airplanes, raising the wing loadings has meant accepting higher and higher minimum flying speeds. The higher minimum speeds, as will be shown later, necessarily mean greater distances for take-off and landing. It has been easier to build long runways than to design the unconventional airplane which can fly either fast or slow. To date, there has not been enough objection to large airfields to force the advent of the STOL airplane.

It can be said that two of the STOL airplanes shown here were pushed aside by contemporary developments considered more important at the time. The Dragonfly I was built when autogyros were at their zenith. Crouch-Bolas were told repeatedly that the autogyro

FIG. 2.

FIG. 4.

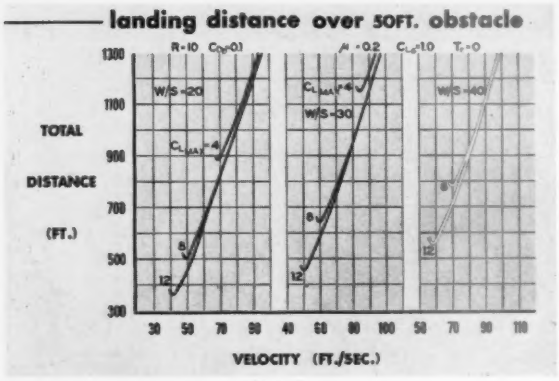


FIG. 5.

was the solution to low-speed flight. The XF5U-1 was under construction at the time jet-engine development was starting in this country. It was known that the turbojet fighters would be some hundred knots faster than the XF5U-1, and this fact doubtless overshadowed the take-off and landing performance of the latter, to the point that a most valuable development was abandoned.

THE NEW URGENCY FOR STOL AIRPLANES

Where there has been, until recently, no clearly seen need for STOL airplanes, there exists today an urgency of the highest order. Nuclear warfare is a demonstrated possibility. An airfield as we know it, with its concentration of airplanes, is an atomic target and may be denied us, *ipso facto*. One of the problems of future military operations is likely to be the distribution of fighting men and materiel forward from temporary bases having less concrete than heretofore. It may also be necessary to carry the distribution farther forward by air than heretofore; if possible, it might be highly advantageous to use aircraft, instead of trucks, right up to the combat units in the forward fringes of battle. Excellent as the helicopter is, it has some limitations in the distribution process, and these may remain with it. If the STOL airplane can overcome these, at the expense of a little more space getting on and off the ground, it would seem that it should greatly facilitate logistic support in future military operations.

The value of the STOL airplane would by no means be confined to combat operations. At home, in the event of a massive nuclear attack, the STOL airplane would be an unprecedented means of transportation for maintaining the nation. For example, great numbers of casualties requiring hospitalization would collect on the perimeter of a nuclear blast. So great would be their number that hospital beds several states away would be needed. The casualties from one P-40 which dived through the roof of a Curtiss-Wright plant one afternoon during World War II left no hospital beds available in Buffalo that night. A fleet of STOL airplanes would be able to land almost anywhere along the blast perimeter, load victims, and fly them at airplane speed in any weather to the doorsteps of hospitals several hundred miles away in any direction. Thousands of lives would be saved which otherwise would be lost. Some way, this service must be provided and be in readiness.

PROBLEMS OF STOL DESIGN

Let us now look briefly at the major problems involved in the design of a STOL airplane. The aerodynamic problems all stem from the necessity for slow flight in order to make short take-offs and landings. This seemingly apparent fact may be questioned. If so, Fig. 5 should demonstrate the point.

Here we have plots of total landing distance to clear a 50-ft. obstacle, versus flight speed. In all cases, the landing distance increases, about linearly, as the speed is increased. The plots apply to a conventional transport airplane or to airplanes having extremely high values of the maximum lift coefficient and have been taken from a parametric study done on International Business Machine card-programed electronic calculators. The landing distance is composed of three parts, as usual: a steady glide, a flare, and a ground roll. The equations used assume a constant flight speed between clearing the obstacle and touching down. I do not yet have a comparable plot for take-off, as we have found the landing generally to be more difficult to compress and have been studying it, but I feel sure that a similar relationship exists between take-off distance and speed. Thus the STOL airplane is called upon to fly "low and slow," a mode of flight abhorred in a conventional airplane.

The aerodynamicists' first problem is to find means of developing lift at low speed. Since aerodynamic forces vary as the square of velocity, it is clear that the aerodynamicists are up against a fundamental difficulty. They are at the juncture, in fact, where years ago other aerodynamicists seeking low-speed flight turned to rotary-wing aircraft. The STOL aerodynamicists today, however, have at their disposal some devices, at least, which the early rotary-wing people did not have. These will be described presently.

The second aerodynamic problem is the development of control forces and moments at low speed. It is akin to that of developing lift but may overshadow the lift problem, in some cases. Low-speed control, over the years, has been one of the most difficult problems of the conventional airplane and will undoubtedly be aggravated in the STOL. The condition of asymmetric thrust worsens rapidly as speed is reduced and for a service airplane may require that all propellers be interconnected so that, if an engine fails, the remaining power is applied symmetrically. In some present airplanes inability to develop sufficient tail down-load at low speed results in a faster take-off speed and greater distance than would otherwise be necessary. This condition may be aggravated in the STOL airplane. It is doubtful that inherent stability will be obtainable in the STOL airplane at the bottom of its speed range. If not, artificial stabilization will be necessary for blind

flying. Again, however, this will be no great problem today.

Apart from aerodynamic problems, the STOL airplane presents its designers with an entirely new problem in alighting gear design. At first blush it might seem that, with the low speeds involved, the landing gear problem would be simplified. Possibly so. But consider again the uses for which these airplanes are intended. They are to land on, turn around, and take off from some open ground over which, perhaps, no vehicle has ever run. Ideally, it should not be necessary to prepare this ground in any way before landing a STOL airplane on it. It is hardly conceivable that a modified conventional gear will answer.

Applicable New Technology

We come now to a consideration of the technology by which it appears that the STOL airplane is possible. Space is lacking here to discuss the control problem, or the alighting gear problem, and we shall limit ourselves to certain means of developing lift at low speed. These include what we at Fairchild have been calling "forced circulation," the "vectored slipstream," "variable thrust incidence," and "direct turbojet support."

Forced Circulation

In this study of landing distance we see that the use of very high lift coefficients on an otherwise conventional airplane results, in some cases, in STOL performance. For example, with a wing loading of 30 lbs. per sq. ft. and $C_{L_{max}}$ of 12, the total landing distance is under 500 ft., and this happens to be without thrust reversal. The approach and touchdown speed is only 50 ft. per sec., or 30 knots. Thrust reversal, as you know, is extremely effective in reducing the ground run and in this case would permit an appreciably lower $C_{L_{max}}$ or higher wing loading for the same 500-ft. distance. Our experience from many calculations is that the corresponding take-off distance will be shorter. But lift coefficients of 12, of course, mean new technology. Present airplanes with propellers may approach a $C_{L_{max}}$ of 4 in landing, if as much throttle as possible is used. Since the lift coefficient is proportional to the circulation about the airfoil, this study suggests forced circulation as the first idea for us to examine.

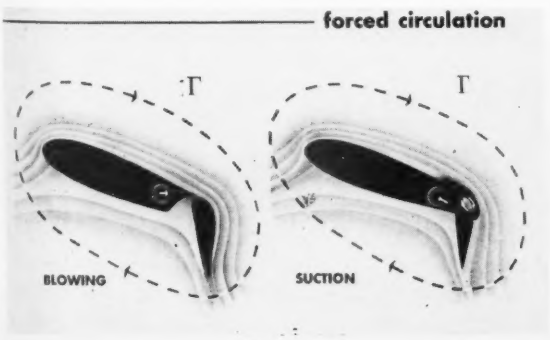


Fig. 6.

Fig. 6 shows two proved methods of forcing the circulation about an airfoil to produce very high lift coefficients. In the airfoil to the left, a slot is provided out of which air under pressure is blown. By means not completely understood, the jet issuing from the slot adheres to the surface of the flap rather than leaving the surface tangentially. In so doing, it apparently entrains much of the flow exterior to it, thereby causing that flow to curve around the flap with a large downward momentum, the reaction to which is high lift. If only enough air is discharged from the slot to make the flow adhere to the flap, the lift coefficient of potential flow for the given flap setting is obtained and the system would be termed "boundary-layer control." If the momentum of the jet is increased beyond that quantity, the circulation is further increased, and the value of the lift coefficient continues to go up as the slot momentum is increased. In the airfoil to the right, a suction slot is provided at the bottom of a cavity having a cusp at the top. When suction is applied to this slot, a vortex of air is trapped in the cavity and spins there as long as the suction continues. The action of the vortex on the external flow is similar, in end result, to that of the blowing jet. A certain amount of suction causes the external flow, which otherwise separates, to adhere to the flap, giving theoretical flap effectiveness. Stronger suction results in forced circulation. These are only two of many possible schemes of forcing circulation. The British have recently tested a slot blowing downward at the trailing edge of an unflapped airfoil. With heavy blowing, such as might be had if the entire efflux of a jet engine were ducted to the slot, a lift coefficient of 11 was obtained.

Fig. 7 is a photograph of an actual test in the Fairchild smoke tunnel in which forced circulation was being obtained by a still different scheme. Note the lines of smoke curving sharply downward and around the trailing edge of the airfoil. In this test our Friedrich Wagner was doing some sleuthing; he was trying to re-enact the setup by which a former German colleague supposedly obtained a C_L of over 30.

Fig. 8 is included to show the condition of the flow, in the previous test, when the circulation control was shut off. The flow may be seen completely separated from the upper surface of the airfoil.

Fig. 7.

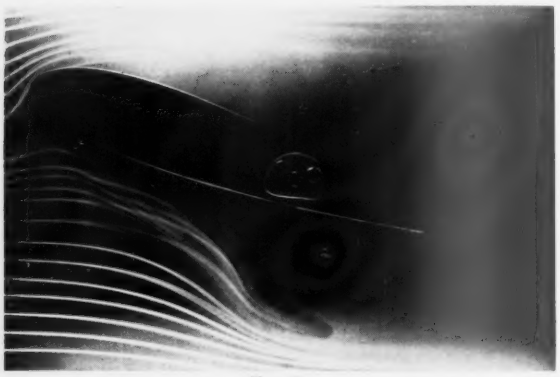


FIG. 8.

I shall not burden you with any layout of the airplane showing how these forced circulation schemes are installed in the three-dimensional wing. Suffice it to say that there is a blower or pump—the heart of the system—which is connected to the spanwise slots by suitable ducting. We envision rather large amounts of power going into the wing.

Forced circulation can be applied equally well to the tail surfaces to obtain the forces needed for airplane control at low speed. A STOL airplane relying entirely on forced circulation for its STOL performance would not differ notably in appearance from a conventional machine.

THE VECTORED SLIPSTREAM PRINCIPLE

The second device for obtaining STOL characteristics is what can be termed the "vectored slipstream." All pilots, and especially Navy pilots, know that the landing can be shortened by the use of some throttle, in a propellered airplane. The vectored slipstream principle seeks to exploit this improvement (Fig. 9).

The idea is simply to employ tractor propellers having high thrust at low speed and deflect as much as possible of their slipstreams downward as sharply as possible by means of the wing, which is fitted with whatever flaps or other auxiliaries will best serve this purpose. You suppose rightly that one of the forced circulation systems might help the deflection. The combination of vectored slipstream and forced circulation will perhaps be used oftener than vectored slipstream alone. The artist has shown a blowing flap in this sketch. The NACA has been making some systematic tests of slipstream deflection, Technical Note 3307 being one of the reports on the program. In these tests, the resultant force R of the propeller-wing combination and the angle θ which it makes with the thrust direction, in the static case, and with the relative wind with forward velocity, are determined. R is the resultant of the propeller thrust and the pressural forces on the wing. In the static case, for a straight wing completely immersed in the slipstream of four propellers, the angle θ was 45° and the lift component L was about 65 per cent of the propeller thrust, with a large, articulated flap. Larger values of θ and L were obtained with auxiliary vanes, and subsequently with BLC on a single flap. You will appreciate the fact that at extremely low airplane speeds, say 30 knots, the lift of the wing in the free stream only is very small—much smaller, for example, than 65 per cent of the thrust of four propellers. Therein lies the benefit of the vectored slipstream. It is apparent that pitching the airplane nose up helps matters. In fact, if the static θ were 70°, a value the NACA actually obtained with auxiliary vanes over the wing, and the airplane were pitched up 20°, the resultant force would be vertical. If the weight of the airplane were then about 90 per cent of the propeller static thrust, the machine could hover.

The configuration of the vectored slipstream airplane will again not be greatly different from the conventional airplane except that the propellers will be larger in diameter and more of the wing will be in the slipstream. There may be unusual controls at the tail, such as jets or airscrews, for low-speed control. As previously indicated, interconnection of the propellers seems to be a necessity, since the airplane will take off and land at speeds far below its power-off stalling speed, and asymmetric thrust must be avoided.

Fig. 10 is included to point out a limitation of the vectored slipstream idea in landing. The airplane is descending with full power along a rather steep, constant-angle flight path. The resultant wing-propeller force R makes the angle θ with the flight path. The problem here is how to reduce the longitudinal component of R, X, to an extremely small value. If X is at all large, a low speed on the descent path will be impossible. Three things might be done: (1) increase the angle θ by more effective vectoring of the slipstream; (2) increase the angle of attack until R is normal, or nearly so, to the path; and (3) increase the parasite drag of the airplane, D_p, by brakes of some sort. There is an objection, in a transport airplane, to too much slope of the floor, which the added angle of attack would cause. The other two solutions appear to be difficult. More study is needed on this procedure.

VARIABLE THRUST INCIDENCE

The landing problem with vectored slipstream suggests the next item of STOL technology which can be termed "variable thrust incidence."

Fig. 11 shows the same propellers and power plants as before, on a STOL airplane which is making a steep power-on landing descent with fuselage floor level. We now have backed off from our previous attempt to obtain the utmost possible deflection of the slipstreams and are using an ordinary set of flaps, which, however, still deflect the slipstreams quite appreciably. In order to get rid of the troublesome downhill component X of the wing-propeller resultant R, we have tilted the thrust axes upward through the angle K until R is normal to the flight path. The tilting has been done mechanically in the first stage of the final approach. Presumably the angle of thrust incidence could be increased until R had an uphill—or drag—component, if that proved de-

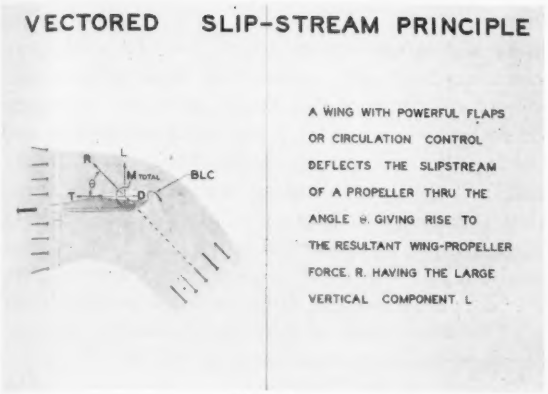

VECTORED SLIP-STREAM PRINCIPLE
A WING WITH POWERFUL FLAPS OR CIRCULATION CONTROL DEFLECTS THE SLIPSTREAM OF A PROPELLER THRU THE ANGLE θ GIVING RISE TO THE RESULTANT WING-PROPELLER FORCE, R, HAVING THE LARGE VERTICAL COMPONENT L
BLC

FIG. 9.

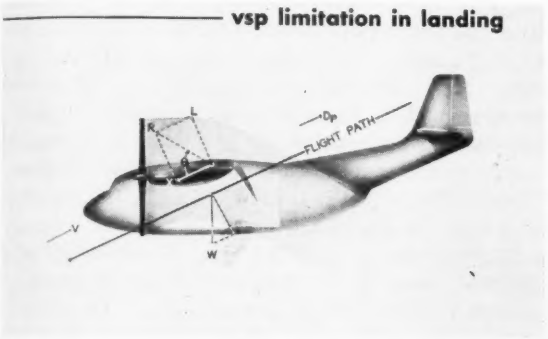


FIG. 10.

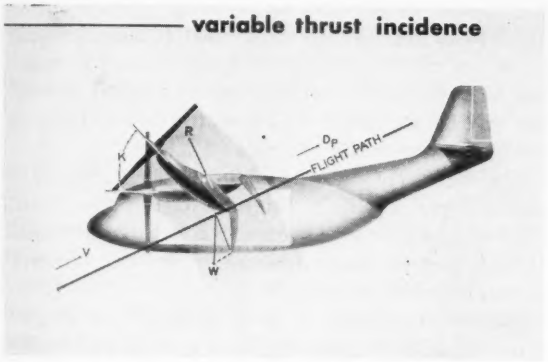


FIG. 11.

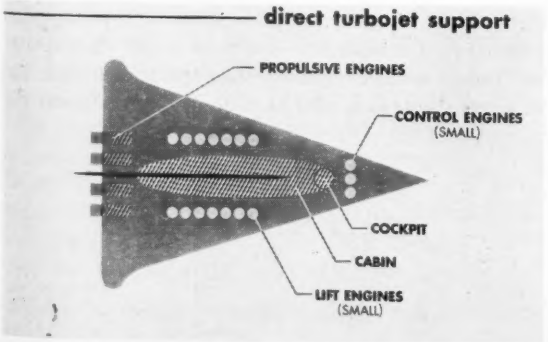


FIG. 12.

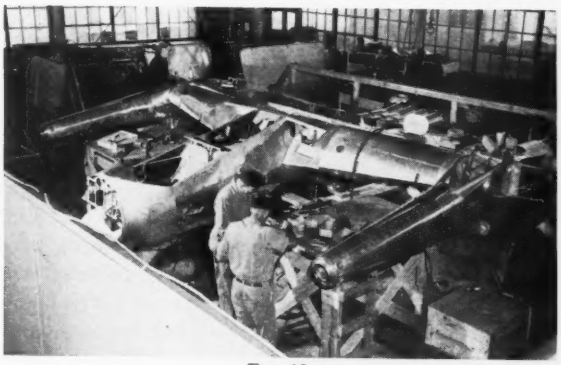


FIG. 13.

FIG. 14

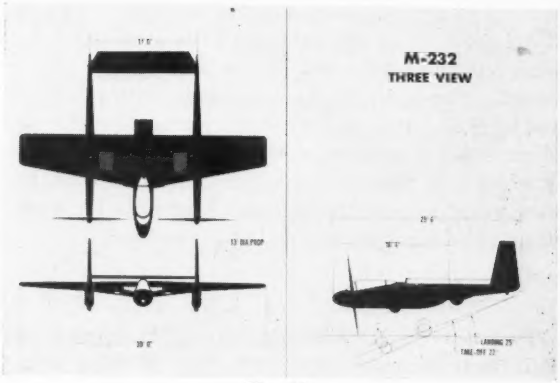


FIG. 15.

sirable. The means of accomplishing the variable thrust incidence best and most simply appears to be by pivoting the wing torque box on trunnions in the fuselage. Power plants will require some modification of their lubrication system to allow tilting. The propellers are subjected to peculiar inflow angles, but the airplane speed is low and these are not expected to cause trouble. Propeller characteristics with these inflow angles are needed, however, at low values of V/nD.

If it comes to a case of vertical take-off and landing, the scheme of variable thrust incidence looks especially attractive. In that event the angle K would be something like 90°.

With either the vectored slipstream or variable thrust incidence, or with some of each, the lift force of the slow-flying STOL airplane comes mainly from its propellers. Anything that can be done to increase the propeller thrust at low speed will improve STOL take-off and landing performance. Little has been done for many years on this aspect of propeller design, and it is hoped that the propeller people will become interested.

Direct Turbojet Support

There may be some readers who consider propellers passé. To them let me say that STOL performance will undoubtedly be possible with turbojet-powered airplanes. Forced circulation may suffice. I have intimated that eventually a hot gas generator somewhat resembling a turbojet engine may power the slots of a blowing forced circulation system. This, however, will involve a lot of development. A more immediate jet application might be that shown in Fig. 12 which we call "direct turbojet support."

Fig. 12, I believe, must be attributed to Rolls-Royce, but others have had nearly the same idea. A turbojet airplane carries a battery of lightweight, downward-directed turbojet engines in the wing roots flanking the fuselage. These engines are used only in take-off and landing, to provide lift by direct jet reaction. An additional group of downward-firing turbojets farther forward provides pitch control if the thrust of the units is varied. The intent in this airplane is vertical take-off and landing. It is possible that a more reasonable airplane would result from accepting STOL performance, in which case fewer lifting engines would be used, the wing would be partially unloaded, and some lift would be provided aerodynamically in the usual way.

New STOL Airplanes Under Construction

Two new STOL airplanes, to my knowledge, are under actual construction. The first of these is the Breguet 940, the culmination of several years of serious study and extensive wind-tunnel tests by a company which has built both conventional airplanes and helicopters. Pictures of this design have been appearing for several years. It is a high-wing monoplane employing the vectored slipstream idea. The straight wing mounts four turboprop engines, shaft interconnected, turning four large propellers, the slipstreams of which immerse the entire wing area. At a design gross weight of just over 14,000 lbs. and useful load of 5,000, the take-off and landing distances come well inside 500 ft. The speed ratio is 8.4. In appearance the configuration is quite conventional.

The second STOL airplane taking shape is a Fairchild development in final assembly at Hagerstown (Fig. 13). Considerably smaller than the Breguet, this airplane has two opposite-turning, interconnected propellers driven by flat engines mounted in the wing at the center of the ship. This airplane also is a vectored slipstream type. Full-span leading-edge slats will reduce the wing pitching moment in the low-speed condition. The long booms position the propellers in a location relative to the wing which is considered advantageous.

One of the propellers is shown in Fig. 14. Made by Sensenich, the blades are wood, and the hubs permit manual variation of pitch in flight. The hubs also permit blade flapping, to eliminate or relieve bending moment caused by large inflow angles. There is no cyclic pitch variation. On the floor is one of the drive shafts which will be installed in a boom. The far end takes the propeller. The right-angled gear box on the end toward us provides all propeller speed reduction and houses the electric screw used to vary propeller pitch. A transverse shaft extends inboard from this box to a box on the centerline of the airplane to which the engines are bolted. This central box includes the necessary overrunning clutches.

The three-view drawing of this airplane (Fig. 15) is included to show that, prior to modification during flight test, at least, its appearance is quite conventional. In fact, its general arrangement follows that of a well-known Fairchild product.

This paper has tried to point out how fixed-wing airplanes capable of extremely short take-off and landing and of normal airplane cruise speeds are now possible, after years during which their development has been neglected. In view of the urgent military need for them—their commercial possibilities completely discounted for the moment—it is to be hoped that numerous types, some exploiting other principles than the vectored slipstream, will soon be in fixtures about the country.

Rear Adm. F. R. Furth,* USN (Ret.)

Project VANGUARD—

The International Geophysical Year Earth Satellite

The technical program involved in the design and construction of the launching rocket and the satellite, the selection of the launching site and the tracking stations, and the determination of the satellite's orbit.

PROJECT VANGUARD represents a practical progression in the techniques of very high altitude research. It is the first step beyond balloons, which cannot go above the earth's atmosphere, and rockets, which cannot stay aloft for an extended time. While essentially an extension of these proved research techniques, the VANGUARD satellite program is the beginning step of a new phase, which presumably will be susceptible of continued improvement to permit longer and higher flights and more advanced instrumentation.

VANGUARD is also significant because of the magnitude of the project. It could not be accomplished without the cooperation of many different organizations with experience in various scientific and technical fields, and extensive logistic support, to establish and maintain a suitable launching facility and tracking stations. Successful construction and launching of the satellite will demand going to the present limits, or beyond, of our engineering knowledge in many fields.

Project VANGUARD is a 3-year project. Many of the broad and most of the detailed engineering decisions concerning the first satellite and its launching have yet to be made. Because of the Navy's prior experience in upper atmosphere research, it has been possible to move ahead rapidly in sketching in the broad outlines we intend to follow.

The subject matter of various papers has underlined the scientific nature of this satellite program. The National Academy of Sciences is sponsoring the satellite program as part of the United States International Geophysical Year effort. The Department of Defense has been charged with responsibility for designing, constructing, testing, and launching a scientific vehicle. Our purpose is to implement the Presidential announcement of July 29, 1955, regarding an earth satellite and to accomplish all the work in time to launch the satellite during the International Geophysical Year.

Within the Department of Defense, the Navy has been selected to manage the technical program. The Army and the Air Force will participate in the prosecution of the technical program. The Chief of Naval Research will manage the program for the Navy and coordinate the program with the other military departments and Government agencies. The Naval Research Laboratory will be the primary organization within the Navy to implement the program.

It is important to remember that both the parent Office of Naval Research and its Naval Research Laboratory are scientific agencies, although their ultimate purpose is to support military preparedness. They have been supporting, and conducting, basic research for many years. As a result, they have the organizational structure, the personnel, and the close day-to-day contacts with the scientific world that are necessary to carry on the VANGUARD program.

Both ONR and NRL are very much at home in the field of upper atmosphere research, in which they have carried on much of the pioneering work. ONR and its predecessor, the Office of Research and Inventions, have supported high-altitude research since 1945. They realized the necessity for a stable platform from which scientific observations could be made to gather information of value in upper atmosphere physics, cosmic radiation, and in connection with future high-altitude flight. Then, as now, the basic problem was to devise a vehicle capable of carrying a pay load to

Presented at the Earth Satellites Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Formerly, Chief of Naval Research.

sufficient altitude and remaining there long enough to make the desired observations.

Inherent limits of aircraft and rubber balloons used in high-altitude studies precluded their use for carrying scientific instruments up to and above 100,000 ft. The development o plastic balloons permitted some advances. (Rockets could go higher but could stay aloft for only an extremely short time. The total flight time for a Viking, for example, never exceeded 10 min.) Instruments could be taken to 100,000 ft. for periods ranging from a few hours to a day or more with balloons. More than 1,000 such flights have been made under ONR sponsorship, and newer techniques that employed balloon-rocket combinations were also devised. Rockets fired from plastic SKYHOOK-type balloons at 70,000 ft. have telemetered scientific information from altitudes of more than 250,000 ft.

The purpose of these balloon and balloon-rocket flights has been to obtain cosmic ray, meteorological, and other geophysical data. The cosmic ray studies have been jointly supported by the Atomic Energy Commission and ONR. The Air Force has also adopted these techniques for high-altitude studies.

The NRL has been using large, high-altitude research rockets since 1946. It has fired twelve Viking rockets and many of the smaller Aerobee rockets. They are instrumented research vehicles that have yielded much scientific information. It is also a matter of interest that the highest photographs ever taken of the earth's surface were taken with a camera mounted in a Viking rocket, from 158 miles up.

The Laboratory as a whole has been doing original work in the physical sciences since its founding in 1923. It is well known for its work in radio and radar, among other things, and for the research carried on in connection with the Viking rocket project. Several of its 13 research divisions are particularly well fitted by experience to contribute to the project. They include Atmosphere and Astrophysics, Optics and Nucleonics. These divisions are well staffed with scientists who are recognized in their fields and who have been prolific contributors to the scientific literature of upper atmosphere research.

Project VANGUARD is being approached as we would approach any other large-scale scientific venture. Since both ONR and NRL have employed, as contractors or consultants, nearly all of the nation's leading scientific authorities in geophysics, astrophysics, and rocket research and have actively participated in these fields, there is no problem of establishing contacts with key people outside the Navy. For the NRL scientists, VANGUARD essentially means accelerated work of the same type they have been performing in the past.

Since the earth satellite problem does differ in several respects from the bulk of NRL's work, however, it will be prosecuted outside the division structure of the Laboratory. A separate project office reporting directly to the Laboratory Director of Research has been established. It will be neither necessary nor desirable to set up a large, complex organization to coordinate the project. Much of the necessary coordination of the technical program is carried out on a day-to-day basis by scientists and engineers at the working level in the Navy and in other services and industry.

The Army and the Air Force have designated Project VANGUARD liaison officers who have official responsibility for keeping their services abreast of the status of the project and who keep ONR and NRL workers informed of their services' potential for participation in any given phase of the work. In addition, the day-to-day coordination at the working level goes on among the services. Army, Navy, and Air Force military and civilian personnel involved in rocketry and other aspects of upper atmosphere research have used formal machinery and informal contacts for threshing out mutual problems for many years. This same working-level communication network is being used to attack problems that must be solved before the VANGUARD satellite can be launched.

The primary difference between VANGUARD and our previous upper atmosphere research projects is introduced by the time element. The VANGUARD satellite will be launched during International Geophysical Year, which ends in December, 1958. It is not possible to proceed with separate component development, building up the rocket and satellite design on the basis of continuing developments in each field and making modifications as component advances permit. The project director and the technical director have had to decide at the outset what the total design is going to be, then go ahead and build it. They will try to develop a complete definition of the specifications before major work begins. Feeding into this are the results of about two dozen design studies now in progress. They represent an attempt to define the entire launching system.

This does not mean that actual work is being held up pending a complete set of specifications. In certain technical areas, we do not have a choice. These are areas where components already developed must be used to the greatest extent possible, and in these areas certain hardware is now being built. The first-stage rocket motor is one example.

The Navy's approach to the management of Project VANGUARD has been shaped by the project's mission. The accomplishment of the objectives requires the fullest cooperation between industry, science, and Government. We have already turned to industry for construction of the three-stage rocket vehicle that will carry the satellite to its orbit.

The Glenn L. Martin Company of Baltimore has been awarded the prime contract for construction of the rocket. This company built the Viking research rockets for the Navy. The first-stage rocket will be of cylindrical monocoque construction, consisting of skin, frames, and longitudinal members, and using integral propellant tanks.

Martin has awarded a subcontract for construction of the first-stage rocket motor to the General Electric

Company of Schenectady, N.Y. This engine will be more efficient than the present Viking engine and therefore more powerful. It will have a thrust of 27,000 lbs. at sea level and an operating time of about 140 sec. The engine consists of a regeneratively cooled thrust chamber, gimballed mounting, propellant valves, turbopump, and high-pressure lines. The propellants will be liquid oxygen and a mixture of ethyl alcohol, gasoline, and silicone oil, which will be forced into the thrust chamber by turbo-driven pumps. The turbine will be powered by the decomposition products of hydrogen peroxide. In this type of turbine, liquid peroxide is converted in a steam generator into hot steam, which is forced against the turbine blades.

This first-stage rocket will be essentially similar to a Viking rocket but improved in two principal ways. The first basic improvement is the more efficient engine. The second is the removal of fins, to produce a rocket that is completely stabilized by the thrust of the motor. This is possible through mounting the motor in a gimbal, which permits controlling the direction of the thrust in any direction by actual movement of the rocket motor. The VANGUARD gimbal mounting will be designed to permit angular deflection of the motor thrust vector by ±5° from the centerline of the vehicle.

The move to a finless rocket illustrates one way in which 10 years of research with the Vikings is valuable background for the present project. It was known in 1946 that the use of fins for longitudinal rocket stabilization produced unwanted moments in roll and added weight to the rocket's structure. Furthermore, they give no assistance to the rocket's course at the moment of launching, when its forward speed is low, and near the end of its powered flight, when it is above the earth's atmosphere.

Another method of controlling a rocket is to mount its motor in a gimbal that will permit the motor to turn so as to direct the thrust as required. A gyroscope controls the direction of the motor. For years many rocket experts have felt that this was the direction in which the development of large rockets should go. The gimbal structure was built into the first Viking, and into all the subsequent ones, although they also had fins to assist in stabilization.

The finless rocket has been under study for about 5 years, and a few small finless rockets have been fired experimentally. The Martin Company has performed much analysis that has proved the finless rocket theoretically workable and has sufficient confidence in this work to go ahead with a large finless rocket for VANGUARD.

The second-stage rocket will also be a finless, cylindrical air frame of monocoque construction. A subcontract for construction of the second stage has been awarded to Aerojet-General of Azusa, Calif. This power plant will also consist of a regeneratively cooled thrust chamber and will be mounted in a gimbal. Nitric acid will be the oxidizer and unsymmetrical dimethyl-hydrazine the fuel. Flow of these propellants to the thrust chamber will be effected by helium pressurization of the propellant tanks, rather than by a steam turbine, as in the first-stage motor.

The third stage of the VANGUARD rocket will be powered by a solid propellant motor and will consist of the motor, a structure for attaching it to the second stage and for imparting spin to the third stage, and the satellite package and mounting structure. Several contractors are now bidding on the contract for building the third-stage rocket motor.

When we come to the satellite vehicle itself, we enter an area necessarily characterized by compromise. Many conflicting requirements must somehow be reconciled. The satellite should be as large as possible, in order that it can be easily tracked by optical means. The bigger the object, the greater will be its visibility. On the other hand, weight considerations demand that the satellite be as small as possible. The scientists and engineers who design and build the VANGUARD satellite will not be worrying in terms of pounds; they will be trying to shave ounces off the weight of the object which ultimately goes into the rocket. So a compromise must be reached in order to build a vehicle small enough to be successfully placed in the orbit yet large enough to be useful scientifically. It must be small enough to fit into the nose of the third-stage rocket. The most desirable configuration for the satellite itself now appears to be a sphere in the neighborhood of 20 in. in diameter.

Other considerations in designing the satellite and determining its pay load stem from the physical stresses to which it will be subjected. It must be transported to altitude in a rocket that has high acceleration and intense vibration. It must be strong enough to withstand the *g*-stress imposed upon it by each of three stages of rocket firing, but strength must be gained without use of excessive weight.

The problem of aerodynamic heating during ascent has been investigated. If the satellite package were to be the nose of the vehicle, it could become too hot, probably in excess of 1,000°F. One alternative in solving this problem would be to build the satellite with a heavy skin and insulation, which could present a problem of excess weight. Another alternative would be to shelter the satellite with a conical, disposable nose for the third-stage rocket. Since the heating would occur during the last part of the first-stage flight and the first part of the second-stage flight—i.e., after high speed has been reached and before the denser portion of the atmosphere is left behind—the conical nose could be jettisoned near or at the end of the second stage. The use of such a cone would provide a weight penalty for the second-stage flight, and this is one of the many factors that is being considered in the weight studies being made in connection with arriving at design specifications for the VANGUARD rockets.

The satellite must survive for a certain length of time after it has been placed in its orbit. While circling the earth, it will face danger from two main sources, temperature extremes and meteoric dust. Solar radiation will tend to heat the satellite and its

pay load to extremely high temperatures, perhaps of the order of 300° to 400°F. While in the earth's shadow, its temperature may drop to well below 0°F. The instruments required for a successful scientific experiment cannot stand wide temperature variations. The temperature range through which certain electronic components, such as transistors, will survive is roughly 40° to 120°F.; this presents a problem of satellite design to stabilize its inside temperature to a satisfactory extent.

It is known that meteoric dust at the altitudes to be traversed by the satellite will cause some deterioration over a period of time. The rate and extent of the harm is not known; in fact, one of the objects of these experiments is to find out the density of meteoric dust in space. This dust might score the surface of the satellite and thus affect its ability to reflect light, with a consequent effect on the inside temperature and upon optical tracking. The assumptions that have been made here on the surface of the earth, in order to arrive at design specifications, might be changed when the satellite gets beyond the atmosphere and is acted upon by meteoric dust. We cannot know until the first one is fired.

The amount and kind of instrumentation in the first satellite is another area in which problems must be solved and compromises agreed upon. Subject to weight and space restrictions, it must send aloft enough instruments to do some scientific work. Much has been written concerning the potential contributions to several scientific fields that might be made by earth satellites. Our job is to put into an orbit an object capable of doing work of importance to each of the scientific fields represented. The first satellite cannot completely satisfy the men in each field—it cannot do all the things they would like to see done. If we tried to build a satellite capable of yielding large amounts of diverse scientific data, we could not get it up into its orbit, and we would wind up with nothing. The VANGUARD technical program must result in a satellite that will be workable, yet scientifically useful. On the technical side, this means sacrifices in terms of accepting larger size and greater weight, with resultant engineering problems. On the scientific side, it means sacrifice in terms of the useful pay load which the first satellite will carry. A reasonable fraction of its weight—perhaps one-fourth—will consist of scientific research instrumentation and its power supply. The remainder will be devoted to structure, a tracking transmitter, turn-on equipment, and power supply.

Several VANGUARD rockets will be built in connection with the program. Because, to be reasonably certain of successfully putting a satellite into an orbit, we must have more than one rocket available.

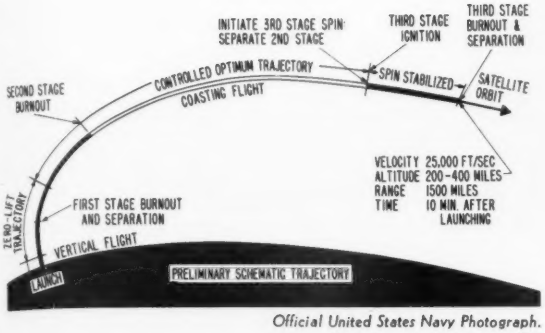
Technically, the chances of failure of a single shot would affect the attitude of everyone connected with building the rocket and its cargo. We are working in a field that places great demands upon everyone's knowledge and calculations of probable performance. Much money is involved. If all of this money and all of this effort were risked on one shot, the project officers and technical workers would be always confronted with the desire to make one more calculation, one more adjustment, or one more test flight before firing, in order to be more certain of success. Yet, to complete the job on time, every step of the program must be marked by bold, confident engineering in which we are prepared to take the consequences of falling short of perfection.

The determination of specifications for the launching rocket and the satellite, and their construction, represent the major phase of the technical program for Project VANGUARD. The project director must be equally concerned, however, with all of the attendant programs required to make it succeed. A launching site has been selected. The VANGUARD satellite will be fired into its orbit from Patrick Air Force Base, Cocoa, Fla. This base meets the operational requirements for large rocket launching and appears suitable to the scientific needs of the program. As soon as the project was established, Navy scientists and scientific and facilities officers began a series of continuing consultations with their Army and Air Force counterparts to determine the best launching site, the requirements for logistic support and how they will be met by the three services, and how problems of establishing and manning tracking stations will be handled.

Several tracking stations will be set up. Each station must have communications circuits linking one another and linking each to a central collecting and computing agency. Each station must have a complement of technicians, observers, and operators, although a minimum of construction will be required. Perhaps one Quonset-type structure for an operations building, trailers, tracking antennas, and communications antennas would constitute a typical tracking site.

Scientists are now working to determine the primary orbit of the satellite and the specific tracking methods. Both optical and radio tracking will be used. Time, speed, and position information from many separate sightings at different tracking stations must be fed rapidly into a central electronic computer, which will determine the orbit on the basis of this information. Data on the orbit must then be broadcast quickly throughout the world to enable scientists of the IGY to pick up the satellite with little difficulty.

(Previous theoretical research is now proving of considerable assistance in working out optical tracking problems. For the past several years, scientists in the optics division of the Laboratory have been conducting studies on the visibility of stars at night and during the day. In connection with this work, calculations were made on the conditions under which small earth satellites might be seen. For purposes of this study, the scientists assumed a satellite that was a 21-in. sphere traveling in an equatorial orbit at an altitude of from 200 to 1,000 miles. As a result of these studies, "it has been concluded that if one knows exactly where and when to look, a satellite when nearly directly overhead



Official United States Navy Photograph.

Official United States Navy Photograph.

Artist's concept of satellite preliminary schematic trajectory.

and at 200 miles altitude would first be visible through 7 × 50 binoculars when the sun is 2° below the horizon, and would be visible to the naked eye for solar depression angles greater than 9°. To see such a satellite easily, however, and to be sure of observing it, when the position is not known exactly, some telescopic magnification such as 7 × 50 binoculars would almost be a necessity and observations of the satellite should not be attempted until the sun is 5° below the horizon.")

When the rocket and its satellite pay load are ready to launch and all of the launching facilities and tracking equipment and stations are in readiness, the Project VANGUARD satellite will be fired up into its orbit. Only a general summary of the procedure is possible at this time, using figures that stem from preliminary design thinking. More precise data must await extensive detailed planning and engineering. The first-stage rocket will start the entire assembly vertically on the first part of its flight, and, when it is a few miles off the ground, its guidance system will begin to steer it gradually toward a horizontal trajectory. When its fuel is exhausted, the first stage will drop off and fall into the sea. This will take place at 30 to 40 miles up, and the rocket will have reached a velocity between 3,000 and 4,000 m.p.h. The second rocket, deflected from the vertical, will continue the satellite upward. It will burn out at about 130 miles up, and the rocket will then be traveling at about 11,000 m.p.h. It will then coast, guided by its own control system, into the satellite trajectory, with only very slight deceleration. At an altitude of about 300 miles, the second stage will separate, fall free, and the third rocket motor will ignite and accelerate the satellite vehicle to a velocity of about 18,000 m.p.h. It may then separate from the satellite proper. The satellite will then be headed horizontally into its orbit, at orbital speed. A portion of the total velocity will be gained by launching the rocket toward the east, to take advantage of the earth's rotation. Thus, before the rocket is even launched, it will have a substantial horizontal velocity because of the rotation of the earth.

The satellite's orbit will be elliptical, rather than circular. Perigee—the point of nearest approach—will be about 200 miles from the earth, and apogee—the most distant point in the orbit—will be about 800 miles out.

The problem of guidance, to ensure that the satellite is projected horizontally into its orbit, is especially difficult. If the angle of entry is either too high or too low, perigee will be too close to the earth, and the satellite will dip into the denser portions of the atmosphere and disintegrate before it has made enough revolutions to complete its mission. It has been determined on the basis of theoretical calculations that the angle of projection should not deviate by more than a few degrees from the horizontal for a launching altitude of 300 miles. If it misses by more than this, the perigee altitude will be roughly half of the launching height, which would cause the satellite to dip well into the denser parts of the atmosphere and cut short its life. The guidance system must therefore be designed to ensure an error of no more than a few degrees in the angle of projection into the orbit.

The consequences of missing the planned orbit are not so serious in terms of the satellite's lifetime but would pose problems of tracking. The satellite will transit different areas of the earth on each revolution. If a revolution is completed in 90 min., as is now contemplated, the earth will have completed roughly one-sixteenth of its daily rotation during this time, so that the satellite will appear at a different longitude for the same latitude on its next trip.

Although the portion of the atmosphere through which the orbit will pass is extremely thin (just *how* thin is one of the facts that the satellite may establish), the cumulative effect of the drag of this thin air will be sufficient to bring the satellite gradually closer to the earth. As the satellite enters the denser atmosphere, it is expected to disintegrate harmlessly in the same manner as a meteorite, because of intense heat and probable mechanical collapse. The lifetime of the satellite is being estimated on the basis of a number of assumptions concerning the composition and density of the upper atmosphere. It may be several days or several weeks or even months, depending upon what is up there.

A simplified analysis of the adaptability of single-disc turbine designs to accessory drives, contrasting the "direct drive" feature of drag turbines to the high rotational speeds of conventional turbines.

Accessory Drive Turbines for Aircraft and Missiles

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Hydro-Aire, Inc.

NOMENCLATURE

A_e	=	effective nozzle area, sq.in.
A_m	=	flow area, in.^{2}
a	=	area, in.^{2}
b_2	=	blade width, in.
c	=	velocity, ft./sec.
c_{th}	=	spouting velocity, ft./sec.
D	=	impeller diameter, in.
g	=	gravitational constant
H_{ad}	=	adiabatic head, ft.
HP	=	horsepower
K	=	throughflow coefficient
N	=	rotational speed
Ma^*	=	peripheral Mach Number
n_s	=	specific speed
p	=	pressure, psia
R	=	gas constant
T	=	temperature, °R., torque, in.lb.
u	=	wheel speed, ft./sec.
v	=	velocity, ft./sec.
V	=	volume flow, ft.^{3}/sec.
W	=	turbine weight flow, lb./sec.
x	=	speed ratio
β_{b-2}	=	blade angle rotor inlet
γ	=	specific weight, lb./ft.^{3}
δ	=	ratio of drag factors
η	=	efficiency
ϑ	=	characteristic design parameter
σ	=	stress
τ	=	sheer stress
κ	=	ratio of specific heats
λ	=	friction coefficient
ν	=	geometry factor
ψ	=	nozzle coefficient
ω	=	angular velocity

(I) INTRODUCTION

AIRCRAFT AND MISSILE accessory power requirements may vary from less than 1 *HP* up to peak values of 100 *HP* or more. This power can be obtained by different means—e.g., by driving the accessory from the pad of the main engine either directly or by means of a constant speed drive, or by auxiliary turbines using bleed air or gas generator gas as an energy source. The use of main-engine compressor bleed air provides expansion ratios from 2:1 (for idle conditions) up to 20:1 (for combat conditions), with bleed temperatures ranging from 700° to 1,300°R. In gas generator applications, higher pressure ratios are commonly encountered (seldom less than 20:1) with temperatures up to 3,000°R. In the following sections some aspects of turbine design for those conditions will be discussed.

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(II) TURBINE CHARACTERISTICS

Most turbine types can be characterized by an effective nozzle area A_e and a diagram showing turbine efficiency η_t as function of the velocity ratio u/c_{th}, where u/c_{th} denotes the ratio of the mean blade speed u (ft./sec.) and the spouting velocity (or theoretical gas velocity) c_{th} (ft./sec.) (see Fig. 1). In these terms, c_{th} represents the maximum adiabatic velocity a gas can attain for a given pressure ratio and temperature and is a measure of the energy level of the gas. The effective nozzle area A_e indicates the amount of gas passing through the turbine since the weight flow usually can be expressed by the term

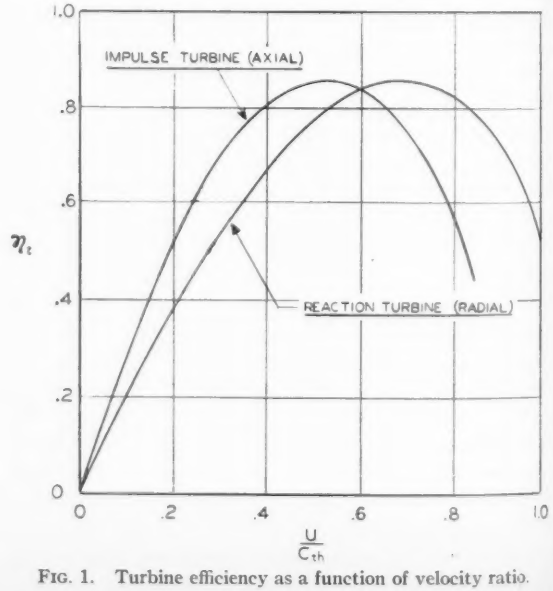

FIG. 1. Turbine efficiency as a function of velocity ratio.

$$W = A_e\psi(p_1/\sqrt{RT_1}) \quad (1)$$

with ψ being a function of the specific heat ratio (κ) and depending on the pressure ratio through the nozzle:

$$\psi = \sqrt{2g\frac{\kappa}{\kappa-1}\left[\left(\frac{p_2}{p_1}\right)^{\frac{2}{\kappa}} - \left(\frac{p_2}{p_1}\right)^{\frac{\kappa+1}{\kappa}}\right]} \quad (2)$$

With these notations the power developed by the turbine becomes

$$HP = (Wc_{th}^2\eta_t)/1{,}100g \quad (3)$$

This equation can be modified by expressing the weight flow in terms of the nozzle area [Eq. (1)], which may be related to the square of the wheel diameter thus making A_e/D^2 a significant parameter for turbine designs. With this term the turbine net power becomes

$$\frac{HP}{c_{th}^4} = \frac{A_e}{D^2}\eta_t\left(\frac{u}{c_{th}}\right)^2\frac{\psi p_1}{\sqrt{RT_1}}\frac{1.48}{N^2} = \vartheta\frac{\psi p_1}{\sqrt{RT_1}}\frac{1.48}{N^2} \quad (4)$$

indicating that the turbine power depends on the characteristic product $\vartheta = (A_e/D^2)\eta_t(u/c_{th})^2$, varying directly with the inlet pressure p_1 and the fourth power of the spouting velocity c_{th} and inversely to the square of the rotational speed N and the square root of inlet temperature T_1.

Depending on the blade form of the rotor and the design geometry of the air passages, optimum turbine efficiencies for conventional single-stage designs are usually reached at u/c_{th} values ranging from 0.45 to 0.8 (see Fig. 1).

These characteristics are typical for existing turbomachinery reflecting common design practice and indicate that radial turbines are usually designed with peak efficiencies at $u/c_{th} = 0.7$. This is almost mandatory for high-speed radial impellers since blade stress loads can be kept within reasonable limits only by selecting $\beta_{b-2} = 90°$ which restricts the peak efficiencies to the above velocity ratio. In axial turbines, the blade angle β_{b-2} does not materially affect the impeller stress load so that axial turbines can be designed for peak efficiencies at smaller or higher velocity ratios.

The effective nozzle area A_e varies with the square of the impeller diameter D in geometrically similar turbines so that the ratio A_e/D^2 is an important parameter for turbine designs. This ratio is proportional to the specific speed n_s, a significant parameter for selecting turbine designs:

$$n_s = \frac{\sqrt{V_3}N}{\sqrt[4]{H_{ad}{}^3}} = \sqrt{\frac{A_e}{D^2}}\sqrt{\frac{\gamma_1(\kappa+1)g\psi}{\gamma_3\,2\kappa Ma^*}}\frac{11.3}{(u/c_{th})^{1.5}} \quad (5)$$

when V_3 denotes the exit volume flow, N the rotational speed, H_{ad} the adiabatic head, γ the density, and when the impeller tip speed u is expressed by the tip Mach Number Ma^*:

$$Ma^* = \frac{u}{\sqrt{[2\kappa/(\kappa+1)]gRT_1}} \quad (6)$$

Considering the interrelationship between peripheral Mach Number, density ratio, and ψ, the relation between specific speed and the ratio A_e/D^2 can be calculated numerically and is represented in Fig. 2 as a function of the peripheral Mach Number Ma^* and velocity ratio. This diagram indicates that the specific speed n_s and the term A_e/D^2 are identical and differ mainly by the peripheral Mach Number.

Considering, additionally, that the width in radial turbines (or blade heights in axial turbines) also depends on A_e/D^2 since

$$b_2/D = (A_e/D^2)/\pi \sin\alpha_2 \quad (7)$$

revealing that small A_e/D^2 ratios imply small blade widths and consequently comparatively high leakage losses, particularly at high Ma^* values, and taking into account the relationship between peak efficiency and specific speed, an approximate relationship between

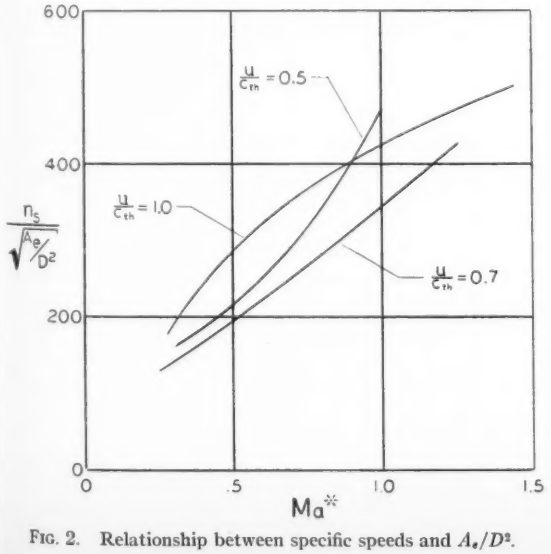

FIG. 2. Relationship between specific speeds and A_e/D^2.

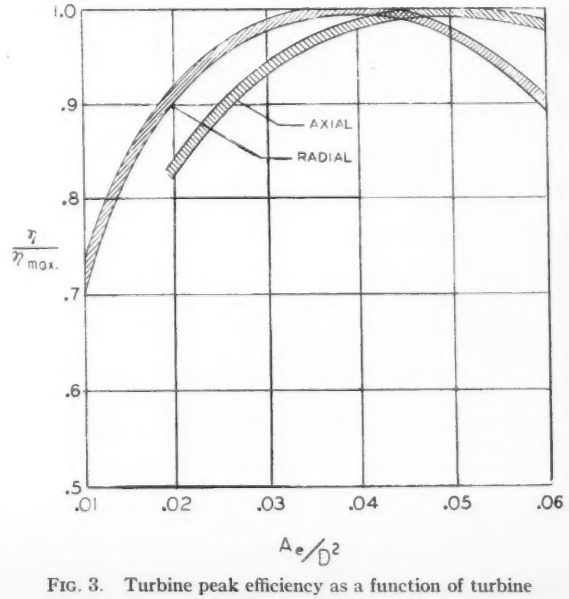

FIG. 3. Turbine peak efficiency as a function of turbine geometry.

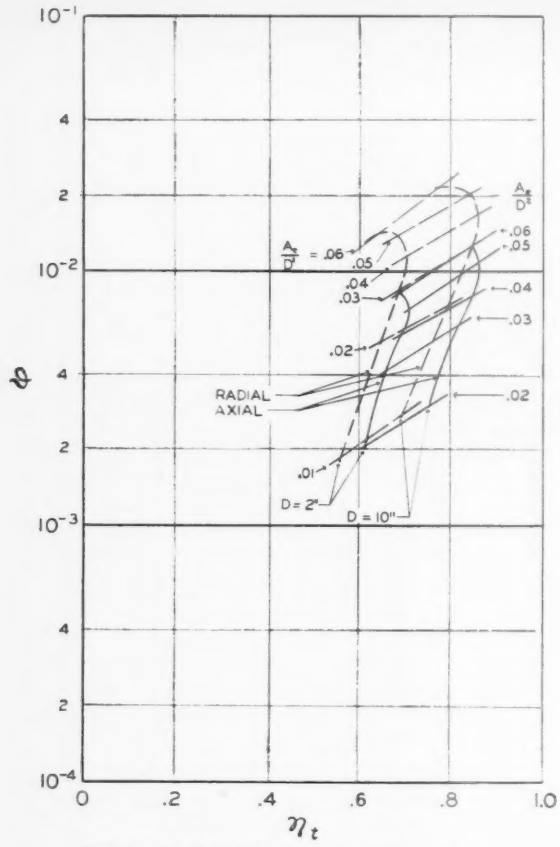

FIG. 4. ϑ values for axial and radial turbines.

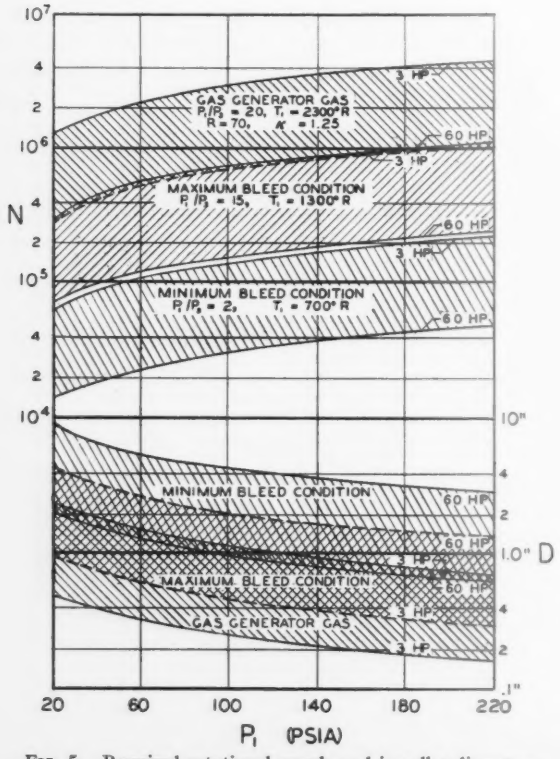

FIG. 5. Required rotational speeds and impeller diameters for $\vartheta = 10^{-2}$.

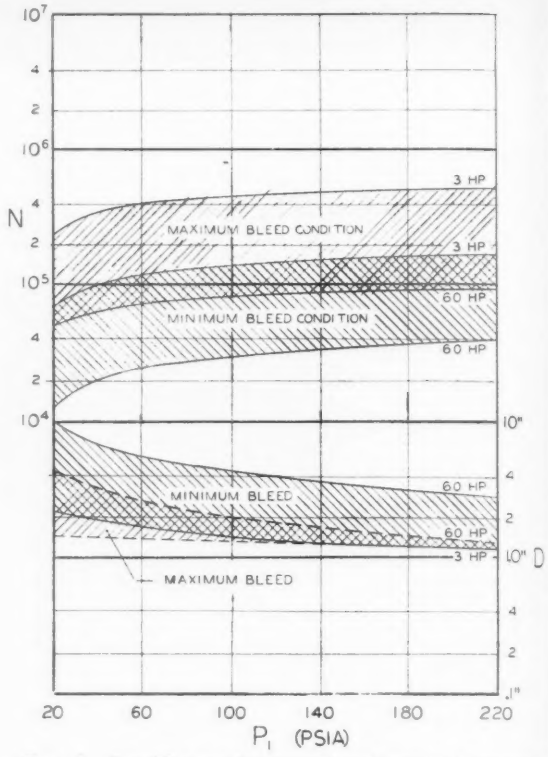

FIG. 6. Resulting rotational speeds and impeller diameters for maximum obtainable ϑ values.

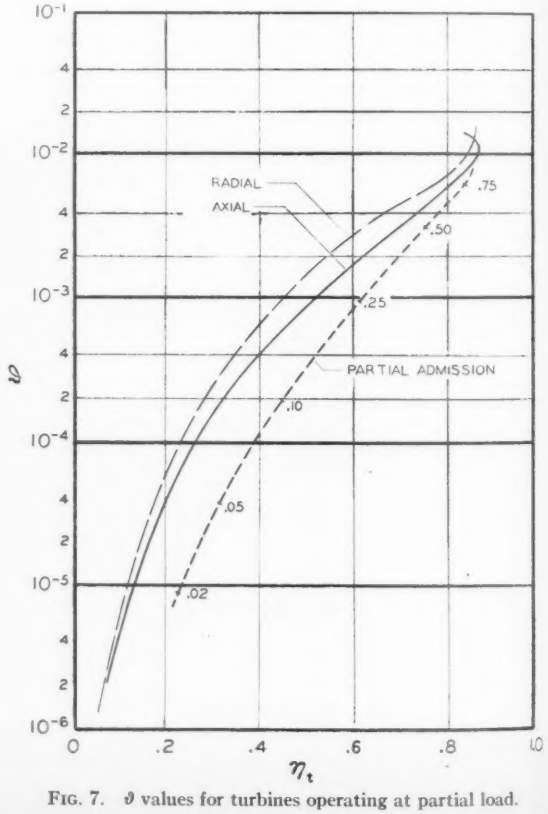

FIG. 7. ϑ values for turbines operating at partial load.

maximum obtainable efficiency and A_e/D^2 value can be established. These considerations indicate that for high pressure ratios A_e/D^2 values of 0.02 to 0.04 will result in maximum efficiencies for single-stage radial turbines, whereas typical values for A_e/D^2 for single-stage axial turbines are $A_e/D^2 = 0.03$ to 0.05. Fig. 3 shows approximate relationships between efficiency and A_e/D^2 which may be considered typical for aircraft and missile accessory drives.

(III) Conventional Turbines for Accessory Drives

With the above values of u/c_{th} and A_e/D^2 the ϑ values for axial and radial turbines vary from 2×10^{-3} for small A_e/D^2 values and small wheel diameters to 2×10^{-2} for high A_e/D^2 values and greater wheel diameters as indicated in Fig. 4. The difference in the corresponding ϑ values for axial and radial wheels is comparatively little, both turbine types requiring about the same rotational speed N in order to generate a certain amount of power for given energy supply conditions c_{th}, p_1, and T_1 [see Eq. (4)]. Since the peak efficiencies η_{t-max} of both types are also about equal, the effective nozzle area A_e will also be equal, which means that the wheel diameter of radial turbines will be higher (about 12 per cent) than the wheel diameter of the corresponding axial turbine because of the different A_e/D^2 values. Consequently, the tip speed of the radial turbine will be higher than the tip speed of the axial turbine, implying higher stress loads for the radial wheel. Because of the different wheel geometrics, however—especially the greater supporting area for the blades in radial impellers—the mean specific tangential stress of the radial wheel is generally smaller so that, in spite of the speed difference, no significant difference in stress loading of impellers has to be anticipated. This means that no outstanding preference for axial or radial turbines appears to be justifiable for initial fixed nozzle design considerations based on rotational speed and impeller stress loading.

Fig. 5 indicates the rotational speeds which would be required for peak performance of these turbine types for different inlet conditions and expansion heads (c_{th}) and outputs from 3 to 60 *HP*, assuming that such units could be designed for $\vartheta = 10^{-2}$. In calculating the impeller diameter, using the corresponding A_e/D^2 value, it is found, however, that for the maximum bleed conditions and usual gas generator energy levels—especially for low *HP* outputs—impeller diameters of less than 1 in. result (lower part of Fig. 5). It becomes apparent therefore, especially when the extremely high rotational speeds ($N = 10^6$ and above) are considered, that $\vartheta = 10^{-2}$ is an impossible design requirement when high bleed air and propellant energy levels must be handled. More reasonable values for these conditions can be obtained only by selecting smaller A_e/D^2 values which inevitably reduces the efficiency as shown in Fig. 4. Fig. 6 shows the required rotational speeds when A_e/D^2 values corresponding to impeller diameters greater than 1 in. are selected. It is apparent that unobtainably high speeds of 500,000 r.p.m. will still be required for the high energy levels, even though ϑ has been decreased to values at which only 50–60 per cent turbine efficiency can be expected. For minimum to moderate energy levels, however, the speed requirements can be kept within reasonable limits (30,000 to 70,000 r.p.m.) without sacrificing efficiency. In all cases, gearing between turbine and accessories is mandatory since accessories usually operate at speeds of 4,000 to 24,000 r.p.m.

By operating a turbine at partial load (lower u/c_{th} values), the speed can be reduced further. This is shown by the upper lines in Fig. 7 where ϑ is plotted against efficiency showing a reduction in ϑ values by a factor of 100 ($\eta_t = 26$ per cent)—i.e., a reduction in speed ($N_\chi/N_0 = \sqrt{\vartheta_0/\vartheta_\chi}$) by a factor of 10. At the same time, the wheel diameter is increased by the square root of the efficiency ratio—i.e., by a factor of 1.82. However, even by operating at these low efficiencies, the rotational speed for typical propellant operation is still above 100,000 r.p.m. for a turbine output of 3 *HP*. For higher turbine outputs and maximum bleed air conditions this mode of operation gives more reasonable speeds—at the cost, however, of increasing the energy supply by a factor of 3.3.

A less costly method of decreasing turbine speeds is the application of partial admission. Fig. 8 shows how partial admission affects the turbine peak efficiency η_{t-max} and optimum velocity ratio u/c_{th}, indicating that both values decrease with decreasing degrees of admission.[1, 2, 3] Since, additionally, the value A_e/D^2 decreases proportionally to the admission rate, the value ϑ changes considerably with decreasing degrees of admission. The dashed line in Fig. 7 shows these values as function of efficiency. Comparing this curve with the corresponding values for full admission turbines (both upper lines in Fig. 7), it becomes apparent that for a decrease in rotational speed by a factor of 10 ($\vartheta = 0.01$ to $\vartheta = 0.001$) the efficiency decreases to about

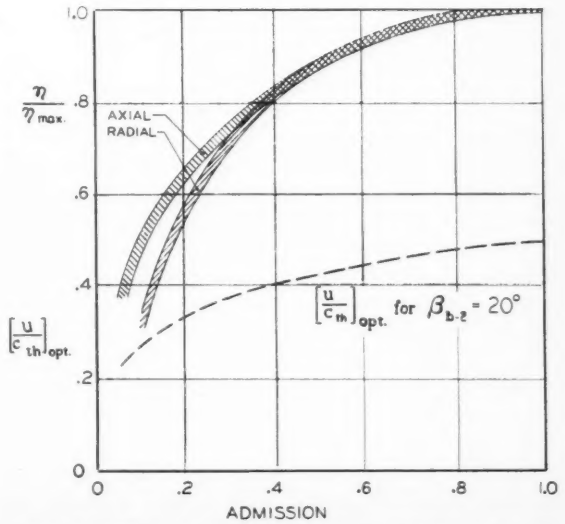

Fig. 8. Effect of partial admission on turbine efficiency and optimum velocity ratio.

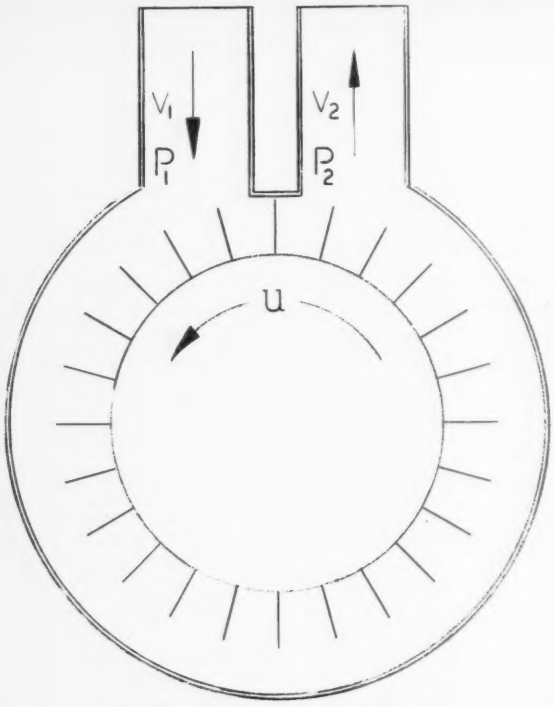

FIG. 9. Schematic of drag turbines.

38 per cent (instead of the 26 per cent for full admission turbines)—i.e., the energy supply has to be increased by a factor of 2.26 (compared to 3.3). The wheel diameter increases with the square root of efficiency ratio and A_e/D^2 values—i.e., in this case (7 per cent admission) by a factor of 5.7, increasing the wheel diameter to about 1 in. for typical propellant-turbines, generating 3 *HP*. The speed, however, for this case is still above 100,000 r.p.m.

It can be concluded from these considerations that turbines of the above designs will require gearing in most cases where small power requirements are coupled with high energy supply conditions (high c_{th}).

(IV) Drag Turbines

Eq. (4) indicates that the turbine must operate at low u/c_{th} values in order to generate small amounts of power at moderate speeds. Peak efficiencies can be obtained at low u/c_{th} values by multistage designs. It is also apparent that the design complexity (sensitivity to tolerances, number of parts, development time) is greatly increased by using multistage designs. In cases where simple designs are called for, the drag turbine offers considerable advantages since its operational characteristic closely resembles that of a multistage turbine. The design complexity, however, is notably smaller than that of multistage designs and even less than that of single-stage conventional designs since this multistage effect is obtained with a single wheel, exhibiting extremely simple blade forms. This turbine type lends itself remarkably well to the generation of small amounts of accessory power because of its extremely small effective nozzle area. Fig. 9 shows the basic features of drag turbines.

The air enters at the inlet port (station 1), goes around the periphery in a corkscrew pattern, and is discharged at the outlet port (station 2) whereby inlet and outlet ports are separated by a block seal. The flow enters the blade passages several times because of the corkscrew pattern so that a multistage effect is obtained. The details of this flow pattern have been investigated on similar units running as pumps. Some of the available references quote flow measurements, indicating the instantaneous direction of the flow at several locations and thus demonstrating the flow mechanism in this type of machine. It is possible, by utilizing this information, to analyze the characteristic of this turbine type by considering the change of moment of momentum of the flowing medium for every cycle of the spiraling flow pass. This type of analysis, however, tends to become complex because of the three-dimensional nature of the flow pattern and the change in number of cycles with velocity ratios and wheel geometrics. A simpler—although not as exact—type of analysis is obtained by considering only the average peripheral components of the flow—i.e., by assuming that the driving effect is proportional to the drag exerted by the throughflow on the rotating part. This type of analysis has been successfully applied[4] for investigating the performance characteristics and performance parameters of drag pumps (also referred to as turbine pumps, regenerative pumps, traction pumps, etc.). Extending these considerations to compressible medii and turbine action, the input head can be represented by the relation

$$H_{ad} = (\tau_{d_r} a_{d_r} + \tau_{f_r} a_{f_r})/A_m \gamma_m \tag{8}$$

when inlet velocity v_1 and exit velocity v_2 have the same value and when τ expresses the sheer stress between the flow and rotor surface (d_r) or between flow and stationary wall (f_r), a the corresponding areas, A_m the throughflow area, γ_m the mean density, and v the velocity in front (1) and after (2) the turbine flow pass. The sheer stress generally can be expressed by the hypotheses

$$\tau = (\gamma/2g) v^2 \lambda \tag{9}$$

with v denoting the shear velocity—i.e., the relative velocity between the flow medium and surface. The turbine torque is

$$T = \tau_{dr} a_{dr} (D/2) \tag{10}$$

so that the turbine output head becomes

$$H_t = T\omega/W = T\omega/(cA_m\gamma_m) \tag{11}$$

with c expressing the throughflow velocity. The hydraulic turbine efficiency, being the ratio of turbine input and output, can then be written in the form ($v_1 = v_2$)

$$\eta_h = x/\{1 + [\delta/(1 - x)^2]\} \tag{12}$$

when the symbol x denotes the ratio of a significant blade speed and a significant flow velocity, and when the sym-

bol δ denotes the ratio of the drag factors of the stationary and rotating part.

The above equation is graphically represented in Fig. 10 which shows that, for $\delta = 0$, a hydraulic efficiency of 100 per cent can be obtained at a speed ratio of $x = 1$. For $\delta = 1$ a maximum hydraulic efficiency of 11 per cent is obtained at a speed ratio of $x = 0.43$. For smaller δ values the efficiency increases together with the speed ratio x. The peak efficiency values of this diagram can now be plotted as functions of the value δ as shown by the solid line in Fig. 11, indicating that efficiences of 50 per cent will be obtained for $\delta = 0.034$.

The input head (Eq. 8) can be represented in the form of a dimensionless head coefficient (assuming $v_1 = v_2$):

$$q_{ad} = H_{ad}/(u^2/g) \approx \nu\{[(1 - x)^2 + \delta]/x^2\} \quad (13)$$

whereby the symbol ν mainly represents significant dimensions of the turbine geometry. The head coefficient q_{ad} is inversely proportional to the square root of the velocity ratio u/c_{th} so that now a correlation can be obtained between the maximum obtainable efficiency and velocity ratio which is graphically represented by the dashed line in Fig. 11 showing that this correlation is mainly determined by the values δ and ν

It is apparent from these diagrams that the value δ determines the maximum obtainable efficiency, whereas the ν value determines the velocity ratio at which peak efficiency occurs. The obtainable δ values can be determined by different methods. One method would be to resort to available information on drag coefficients for different types of surfaces. This approach, however, requires an extremely careful and critical analysis giving due consideration to the flow patterns prevailing in the rotating and stationary channel. Another approach would be to analyze all the δ coefficients which have been obtained in the previously mentioned pump investigations since the maximum obtainable efficiency for this type of machine, operating as a pump or compressor, can be expressed by the value δ. The solid line in Fig. 12 shows the dependency of the hydraulic pump efficiency on its δ value, indicating a δ value of 0.09 for the already obtained pump efficiency of 48 per cent. This means then, according to Fig. 11, that turbine efficiencies of 39 per cent are possible. The obtainable ν values for pumps and their relation to the δ value can also be derived from this analysis, since the pump head coefficient also is a function of δ and ν, as indicated by (see dashed line in Fig. 12)

$$q_{ad}^* \approx \nu\{[(x - 1)^2 - \delta]/x^2\} \quad (14)$$

The evaluation of pump data indicates that ν values of 20 have been obtained with pumps, implying that the above-quoted turbine efficiencies of $\eta_n = 0.39$ can be obtained at velocity ratios of $u/c_{th} = 0.2$.

This estimate must be considered conservative since the δ and ν values calculated from pump test data include leakage losses through the block seal. These losses are more detrimental in drag pumps than in drag turbines since in pumps the leakage occurs from outlet port to inlet port—i.e., the fluid leaks after it has absorbed the energy of the compression process. Additionally, the leakage is in direction of wheel rotation and therefore is high compared to leakage in drag turbines where the leakage is from inlet to exit port—i.e., against wheel rotation. The reduced leakage effect in turbine action and additional consideration dealing in more detail with the actual flow pattern in drag turbines and drag pumps indicate that lower δ values and higher ν values than indicated above can be obtained. This means that higher turbine peak efficiencies are obtainable and that the optimum velocity ratio can be reduced with further development. The lower part of Fig. 13 shows a selection of precalculated turbine characteristics, reflecting the previously discussed tendencies—i.e., increasing peak efficiencies with decreasing δ values and decreasing optimum velocity ratios with increasing ν values. The cross-marks in this diagram show Hydro-Aire test results of one of the later experimental units indicating satisfactory agreement with the precalculated data, especially at low u/c_{th} values. The discrepancy between analysis and test data at higher u/c_{th} values is accounted for by the wheel disc friction losses which have been neglected in the analysis for simplicity reasons.

The weight flow through the turbine is determined by the relation

$$W = A_m(p_1/\sqrt{RT_1})K(c/c_{th}) \quad (15)$$

whereby the factor K is a throughflow coefficient and similar in definition to ψ but numerically about 50 to 100 per cent greater. The expression c/c_{th} can be directly calculated from the previous analysis and depends on δ, ν, and u/c_{th}. Some precalculated values are shown in the upper part of Fig. 13.

Comparing Eq. (15) with Eq. (1), it becomes apparent that the effective nozzle area of drag turbines can be expressed by the relation

$$A_e = (A_m K c/c_{th})/\psi \quad (16)$$

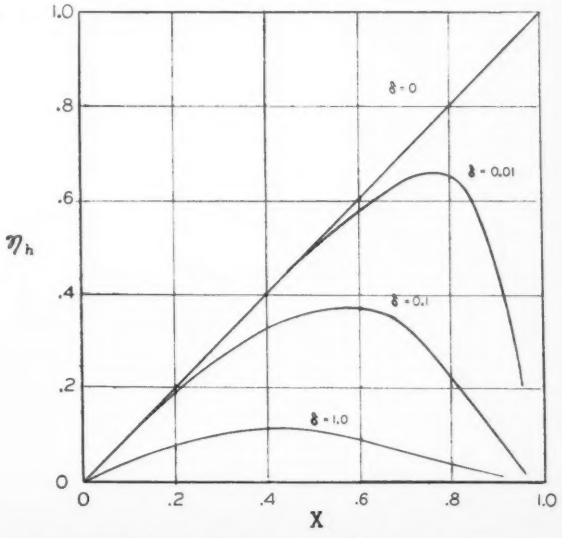

FIG. 10. Basic relationships for drag turbine performance.

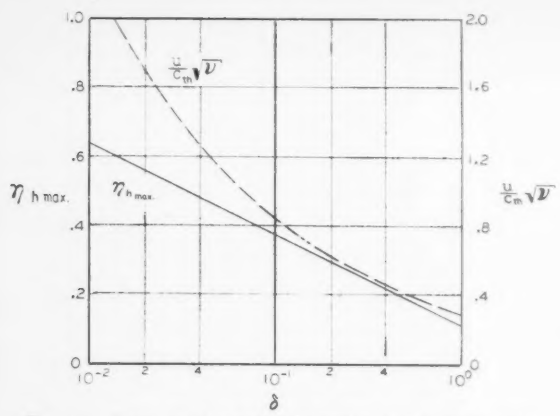

FIG. 11. Drag turbine peak efficiencies and velocity ratios as functions of δ.

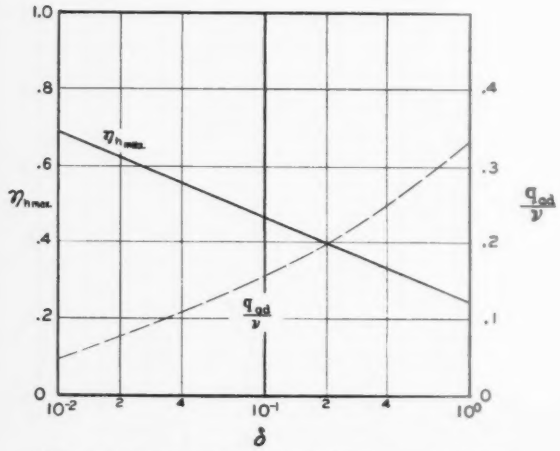

FIG. 12. Drag pump peak efficiencies and pressure coefficients as functions of δ.

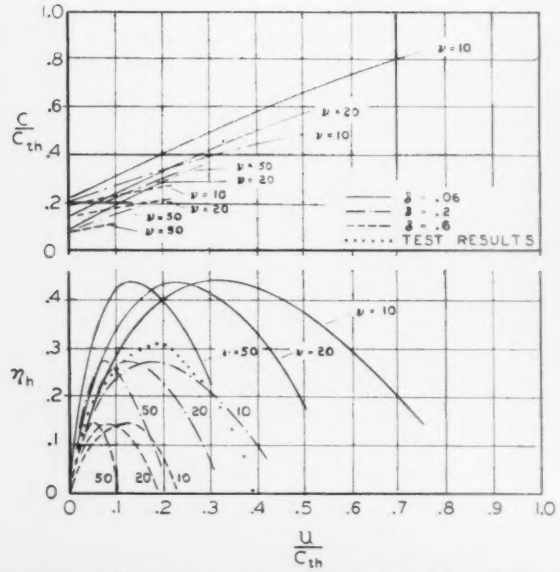

FIG. 13. Drag turbine performance charts and test values.

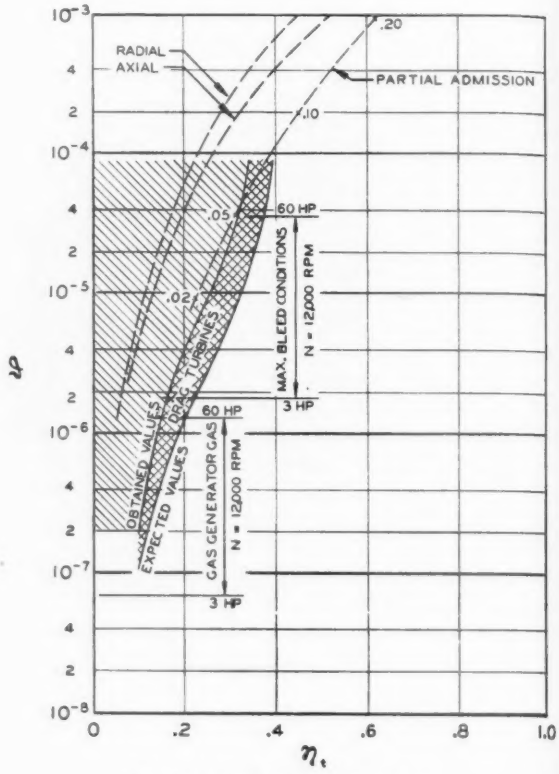

FIG. 14. ϑ values for drag turbines.

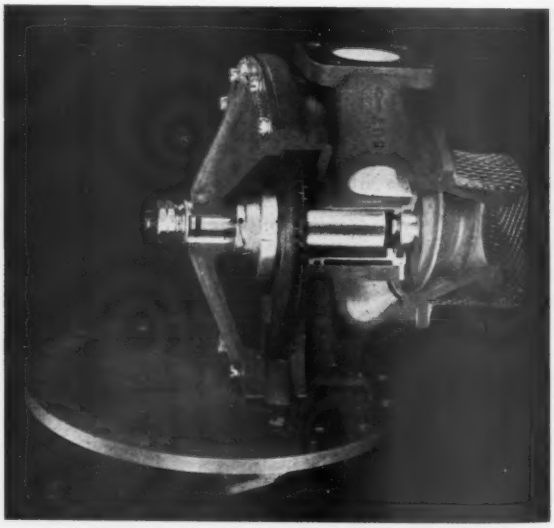

FIG. 15. Cutaway view of turbine-driven fuel pump, employing drag turbine.

indicating that the throughflow area of drag turbines is considerably greater than the nozzle area of the corresponding conventional turbine. This means that drag turbines have greater flow channels than conventional turbines passing the same amount of flow. This feature is of special importance in cases where low turbine outputs are desired at high energy supply levels (propellant) and favors the producibility and unit cost of drag turbines considerably, especially when the simple channel geometry of drag turbines is compared with the frequently required convergent-divergent supersonic nozzles and airfoil shapes of the blading in conventional turbines.

Another advantage of the drag turbines can be shown when the ϑ value of this turbine type is considered. With Eq. (16) expressing the effective nozzle area and ν expressing significant dimensions of the turbine geometry, an expression for the A_e/D^2 value for drag turbines can be formed which shows that A_e/D^2 is essentially proportional to the ratios K/ψ and c/c_{th} but inversely proportional to the product $\nu\delta$. Hence, the ϑ value can directly be calculated and assumes values which are shown in Fig. 14 as functions of efficiency. In this diagram, the shaded area indicates a region substantiated by Hydro-Aire test results whereas the cross-hatched area indicates the region obtainable with ϑ and ν values obtained in pump investigations. This, however, cannot yet be considered as a limit for the drag turbine potential since considerable improvement in δ and ν values must be expected with further development.

Comparing the ϑ values of drag turbines with ϑ values of conventional turbines (dashed lines in Fig. 14), it is apparent that the drag turbine covers considerably lower regions than even the partial admission turbines and that the presently obtained efficiencies, although low in absolute values, are slightly higher than those of partial admission turbines for equal ϑ values and can reasonably well be expected to be improved to 50 per cent higher values (cross-hatched area in Fig. 14) for ϑ values smaller than 10^{-5}. The importance of the region $\vartheta < 10^{-5}$ is highlighted by the fact that ϑ values of 10^{-7} are desired for 4 *HP* gas generator turbines operating at 12,000 r.p.m.—i.e., at a speed which allows direct coupling with the accessories without gearing. Such "direct drive turbines" offer considerable advantage with respect to unit simplicity, reliability, cost, envelope, and weight, especially when "integrated designs" are considered—i.e., designs in which turbine wheel is mounted directly on the overhung shaft of the accessory. This is demonstrated by the cutaway view, Fig. 15, of the recently developed turbine driven fuel pump, employing a drag turbine as drive, mounted directly on the pump shaft. Fig. 14 points out the low ϑ values required for such designs, assuming a rotational speed of 12,000 r.p.m. for cases where the gas supply is of the high energy type. It is also apparent from this diagram that the drag turbine appears to be the most promising type for this application, offering higher efficiencies than the other designs. The wheel diameter required for drag turbines operating at these ϑ values will be of reasonable size and are unlikely to exceed the accessories' envelope diameter in most applications because of the flexibility of the geometric design parameters (ν values). As a result of the low rotational speed, only small to moderate wheel tip speeds are required, providing stress loads which most likely can be handled by cermets of presently produced qualities—especially for short-time duration—and thus making direct drive turbines energized by high-temperature gases more feasible.

The above considerations can be simplified further when it is considered that the ϑ values can be correlated to the ratio HP/p_1 (*HP* over inlet pressure) through the rotational speed, pressure ratio, and gas temperature. Such an analysis indicates to some degree which turbine type gives the highest efficiencies and reveals that, for rotational speeds from 10,000 to 20,000 r.p.m., drag turbines in general achieve higher efficiencies than conventional single-stage types if the HP/p_1 value is less than 0.05. For HP/p_1 values of 0.1, partial admission turbines become competitive efficiencywise at these speeds, whereas HP/p_1 values of 10 and higher point to conventional designs.

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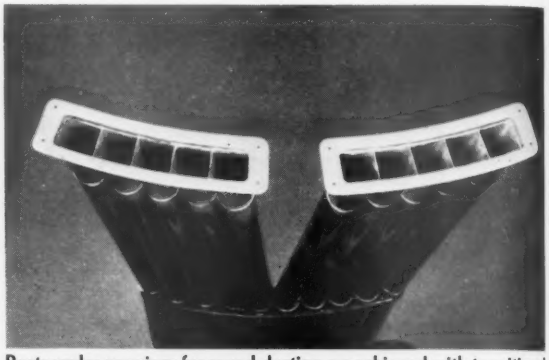
Pneumatic Ducting Systems

A description of the design and manufacturing problems of a power transmission system for compressor-bled air.

William M. Cattrell,* Ryan Aeronautical Company



Rectangular openings for round ducting are achieved with transitional sections in this afterburner cooling duct system.

Introduction

Pneumatic systems to transmit heat and power offer one of the newest, most promising solutions to the growing demands of accessories in aircraft. The high speeds, high altitudes, and extended ranges of today's planes necessitate minimum structural weight and increased propulsive power. At the same time, requirements for auxiliary power are rising because of increased pressurization, air conditioning, flight controls boost, and automatic operation.

Pneumatic power offers many advantages over electrical, hydraulic, and mechanical methods. By means of air turbines, piston and cylinder actuators, and jet pumps, bleed air can be used to accomplish practically every auxiliary function.

Air is light in weight, available everywhere, and simple to use. It requires no return system. It is safe because it will not burn, and it eliminates the possibility that the wrong fluid may be fed into a system. Air lends itself to system integration, which enhances reliability. A single pneumatic system can take energy-laden air from main power plants, air-borne auxiliary gas turbines, or ground facilities. Pneumatic ducts in multiengined planes can be manifolded together so that loss of an engine will not seriously impair the system.

But the selection of power components and the design and fabrication of ducting require extreme care and advanced knowledge if benefits are to be realized. Every task, from propelling the plane to performing the auxiliary functions, is accomplished by the energy in the fuel carried.

Normally, it is more efficient to transmit power through shafted systems than through pneumatic. Therefore, a pneumatic system must have high overall efficiency if the fuel consumption charged to it is to be justified. This is attained only when the ducting system is carefully matched and balanced with the temperature, pressure, and velocity of the airflow and the power drive components used.

These structures are not simply air pipes, plumbed together with standard fittings, which can be fabricated by any sheet-metal shop. Like exhaust equipment for jet and piston engines, these systems must handle large volumes of high-temperature, high-pressure gases (air). But because pneumatic ducting must transmit power throughout an airplane and is therefore required in substantial quantities, it must be built from extremely light gage alloys to keep weight within tolerable limits. This imposes completely new design and manufacturing problems, many of which have not previously been explored by industry.

Pneumatic ducting requires high temperature-resistant alloys, such as stainless steel, because temperatures range from 500° to 900°F. These alloys also possess yield strengths at elevated temperatures such that gage thicknesses can be reduced to a range of 0.008 to 0.020 in. to keep weight down. Within these thin-walled systems, pressures from 50 to 250 psi and velocities ranging to the speed of sound at sea level (764 m.p.h.) must be handled.

The problems are magnified by the need for flexible, leak-resistant joints to accommodate the extreme differential in thermal expansion between the ducting system and the air frame. Flexible joints are also required for transmitting power to movable aircraft surfaces. At

* Research Group Engineer.

the same time, the number of joints, fittings, turns, and discontinuities must be kept to an absolute minimum to avoid all losses due to induced drag and turbulence.

Advantages

Air bled from the compressor stages of turbojet or turboprop engines can provide the major source of pneumatic power because this air is already energized to do the job. With a properly designed ducting system, compressor-bled air can be integrated with external engine-starting auxiliary power sources, internal gas-turbine drives, and ram air systems. This versatility lends itself to the ultimate objective of making the airplane self-contained, which increases mobility and reduces turnaround time at airports.

Pneumatic ducting systems, fed with compressor-bled air, provide decided advantages over other methods of power transmission in simplicity, reliability, ease of maintenance, safety, and weight-saving.

Weight can be saved in several ways. Power is transmitted through lightweight, air-filled tubes instead of heavy cables and oil-filled conduits. No fluid reservoir is required because the system is not a closed type and the air is dumped overboard after use. Motors and actuators can be placed in the fuselage, close to the points of power application, thus shortening cable and conduit runs and simplifying maintenance through increased accessibility.

Another weight-saving feature is the adaptability of pneumatic ducting to multiple applications. In one design, a 2-in. diameter system was adequate for powering an air-conditioning unit. By enlarging the ducting to a 4-in. diameter, the same system could also handle an air-turbine drive for accessory use. Only 65 per cent of the weight of the system was charged to the air-turbine drive because 35 per cent was already assigned to the air-conditioning requirement.

Because pneumatic systems use fewer sources of power and shorter cables and hydraulic lines, they are inherently simpler, making them more reliable and easier to maintain.

One of the important advantages gained is the improved simplicity of an aircraft's main-engine structure. Increased numbers of accessories are being placed on the engines to serve multiplied requirements of the latest aircraft. These accessories have expanded the diameter and length of engine nacelles, adding frontal drag and adversely affecting performance.

With pneumatic systems, the engines can be kept clean of shaft-driven accessories. This permits slimmer, shorter engine nacelles which lend themselves to the requirements of wing and pod-mounted power plants. Because the engines are relieved of the accessories, they are lighter, and the wing and pod structures can also be made lighter.

Welcome savings in time and money are realized when engines are to be replaced or repaired. Power plants can be quickly removed without bothering with disconnecting a host of engine accessories. A salient maintenance feature is that the entire pneumatic system can be checked out with ground sources of air without using the main engines.

Safety is enhanced by use of pneumatic systems because air-filled tubes are substituted for hydraulic lines, which can burst into flames when ruptured as a result of accident or combat-caused damage.

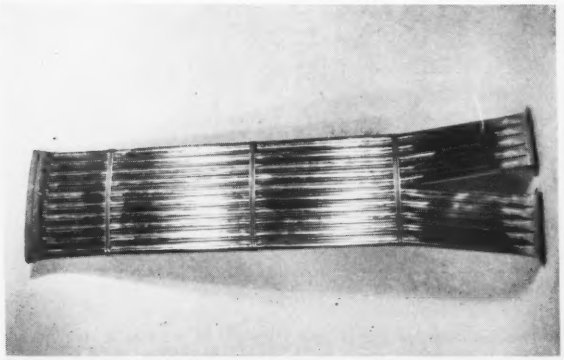
Auxiliary Power

Pneumatic ducting systems can provide power for all aircraft needs now supplied by electrical, hydraulic, and mechanical means. Compressed air from main-engine compressors or gas turbine-driven pumps can be used to drive air turbines, electrical alternators, hydraulic pumps, and direct mechanical actuators. Through these devices, aircraft can be pressurized, heated, cooled, and ventilated for the comfort of personnel and to ensure satisfactory operation of equipment.

The simplest method of air conditioning is to take compressor-bled air directly to the cabin through refrigerating and flow control devices. Care must be exercised to avoid, or screen out, all engine contaminants which might cause irritation.

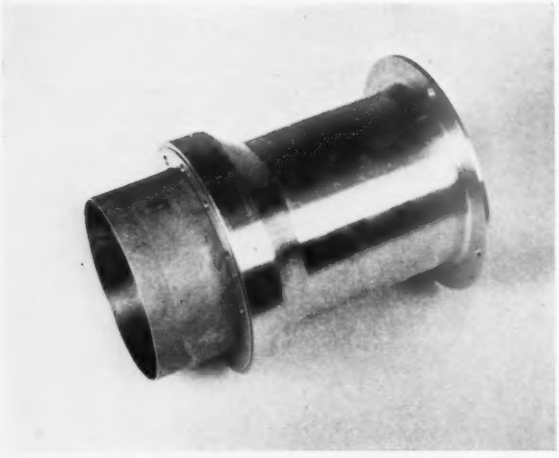
Another technique involves the use of compressor-bled air to drive separate cabin superchargers. This

Physical test section of Ryan laboratory where pneumatic ducting, joints, and fittings are evaluated under conditions simulating actual flight.

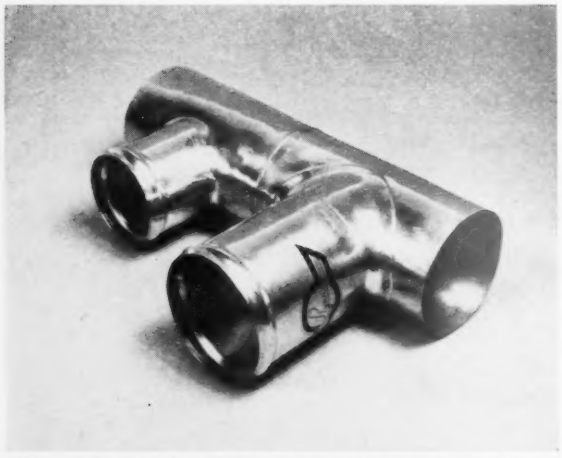


Ducting system for taking ram air and cooling high-temperature afterburner sections is shown in this fabricated structure.

Flexible ball-type socket, designed by Ryan, is leak-resistant means for providing universal duct movement and rotation.



Slip-type joint accommodates linear movement due to thermal expansion needs. Joint is of all-metal construction, with replaceable seals.



Two methods for branch line take-offs of pneumatic ducting are shown in stainless steel, 0.010-in. gage. Arc welding, spot-welding, and brazing are joining methods. Note good ductility of sections indicated by smooth beading.

system is lighter than shaft-driven superchargers because no gear box is needed. It is more complicated than using compressor-bled air directly, because a heat source must be provided and compressors must be regulated for varying altitudes.

For ventilating and moderately cooling certain types of air-borne equipment, ram air picked up in flight may serve. This air can be picked up with air scoops and ducted to equipment and cargo areas.

For operating landing gear, flaps, and control surfaces, pumping fuel, and actuating jet-engine nozzle controls, the designer must select the combination of power transmission systems which best fits the overall requirements. Substantial amounts of electric power can be generated by operating alternators from compressor-bled air. To meet constant frequency needs, it is necessary to provide means of compensating for the variation in air temperature and pressure during flight. This can be achieved by using a variable nozzle with the air-turbine drive for the alternator.

For hydraulic power, compressor-bled air may be employed with simpler regulation because hydraulic pumps will produce adequate pressure and flow over a wide range of engine speeds. Emergency power for both electrical and hydraulic systems can be made available by installing small air turbines which will operate on compressor-bled air in flight and compressed air from auxiliary gas turbines on the ground.

Engine Starting

As turbojet engines have increased in thrust, the torque required to start them has also risen to the point where pneumatic starting systems are now preferred. They are simple and lightweight. They usually consist of an air turbine, geared to the main engine, which may be energized by a compressed air source that is either air-borne or ground-located.

On multiengined aircraft, the first engine may be started in this way, and the others may be activated by air bled from its compressor. Where the airplane must carry a self-contained starting system, a hot gas turbine can feed gas to the same type of turbine starter which is modified to accept high-temperature gas.

Boundary-Layer Control

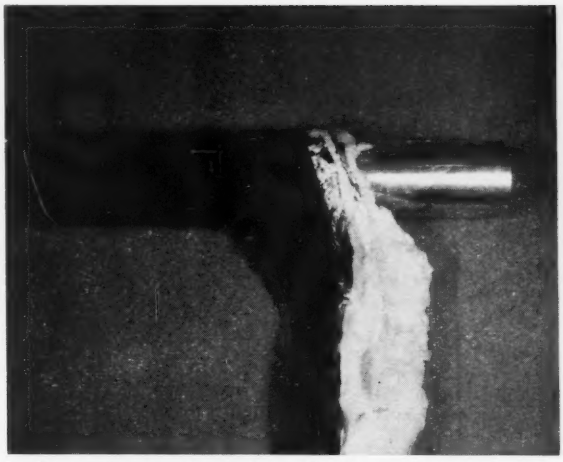
Boundary-layer control may soon become an aircraft requirement because of the advantages in increased pay load and reduced landing speeds which it has demonstrated. Insulated ducts can be used to carry large airflows from engine compressors to wing sections.

In some cases, turbocompressors may be employed to provide efficient delivery during periods when air speeds are low and boundary-layer control is most useful.

Anti-Icing

Like boundary-layer control, anti-icing of aircraft surfaces requires large volumes of air. From a standpoint of installed weight and simplicity, this heated air can best be obtained from the main-engine compressor and

Short-radii bends in 0.010 in. stainless steel are easily formed. Note heavy flange seamwelded to thin-gage tubing.



Insulation of pneumatic ducting with silicone glass cloth, which withstands 450°C., has proved effective.

injected directly into the structures to be protected. If the air temperature is too high for the aluminum surfaces, added quantities of cooler air may be picked up and mixed with it. This will also reduce the drain of air taken from the propulsion power plants.

Dynamic Control

The dynamic control of aircraft in flight with compressed air is another new development which is receiving attention. This technique, which has been demonstrated in the British "Flying Bedstead" test vehicle, may be particularly valuable in stabilizing the flight of VTO and helicopter aircraft because they operate at such low air speeds that conventional controls may be inadequate. In these applications, yaw, pitch, and roll control may be achieved in hovering aircraft by exhausting compressor-bled air from special ducts at air-frame extremities. Reverse thrust effects may also be augmented by using compressed air to deflect the main jet stream or to actuate and cool reverse thrust deflector mechanisms.

General Design Considerations

The functional aspects of pneumatic ducting systems involve complex aerodynamic and fluid mechanics problems which the designer must resolve.

Compressor-bled air from main engines is a tempting source to tap, but this air is not free. A great deal of work has been done by the engine's compressor to give it the energy it possesses. If full advantage is not taken of each pound of energy-laden air, an undue penalty in fuel consumption is paid.

When air is taken from the engine, the turbine wheel and tailpipe are deprived of mass flow. This tends to slow engine speed and reduce thrust. Most turbojets are automatically speed-governed so that additional fuel is brought to the engine to restore the speed and thrust. This extra fuel consumption must be balanced against the advantages gained in using pneumatic power.

The designer must carefully weigh every factor, such as the reduced frontal drag of the engines due to the removal of the accessories and the lighter installed weight of the pneumatic system in developing the system.

Aircraft requirements are so varied that there are no universal design patterns. Each airplane and engine combination must be analyzed in the light of the specific equipment to be served; the temperature, pressure, and flows of the air available; and the mission of the airplane.

A suggestion to improve technical decisions by subordinating performance considerations in design to military operational suitability.

Air Operations Consciousness in Aeronautical Engineering

Ralph H. Miner*
Lockheed Aircraft Corporation

STATUS, YEAR 1956

WE RECOGNIZE, of course, that industry and the military share with equal interest a desire to correct an inadequate design engineering philosophy—a philosophy not yet geared to the precipitous operational environment of this era. We need, then, a higher level of air operations consciousness among aeronautical engineers. With this in mind, I am going to attempt to outline the gravity of the situation in terms of the state of aeronautics as a whole. From this, a plan will be offered for an *organic change* in the engineering decision base.

In building our platform for discussion of the design engineering province, let us first note briefly the current state of three major areas of aeronautical endeavor: the commercial scheduled air lines, military inhabited aircraft, and military uninhabited aircraft. The current state of each activity will be indicated by comparing "gross accident picture" with "performance regime." All accident data referred to will be from January, 1954, to date. It should also be noted that, while some of my preliminary remarks will appear rather fundamental, it is the relationship of one factor to another that I wish to underscore.

Consider the state of our commercial scheduled air lines. The scheduled air lines have, for some time, been considered by our insurance houses as normal risks, with premiums comparable to all other forms of transportation. Observe that after several years within their present 200- to 400-knot performance regime, the scheduled air lines have achieved operational stability—that comfortable point at which casual, steady-state refinement can take place. This operational stability is evidenced in the safety record of the commercial scheduled air lines. In fact, for the period of time in question, we are able to count their serious accidents on the fingers of our hands

Now consider the military inhabited aircraft picture. Since January, 1954, several thousand serious accidents have been experienced by our military air services. It would not be proper, of course, to compare the military accident picture with the commercial. We can, however, make an observation. We noted the operational stability in the air lines 200 to 400 regime. The observation I wish to make is in connection with the military's current 500- to 700-knot performance regime, in which, our accident picture tells us, operational stability has not yet been attained. While we will in due time attain this operational stability, a serious concern is that production plans for the inhabited aircraft of the next era—those in the 700- to 1,000-knot regime—are proceeding without a current background of operational stability. This is a significant point in our penetration of the design engineering organization. More on this later.

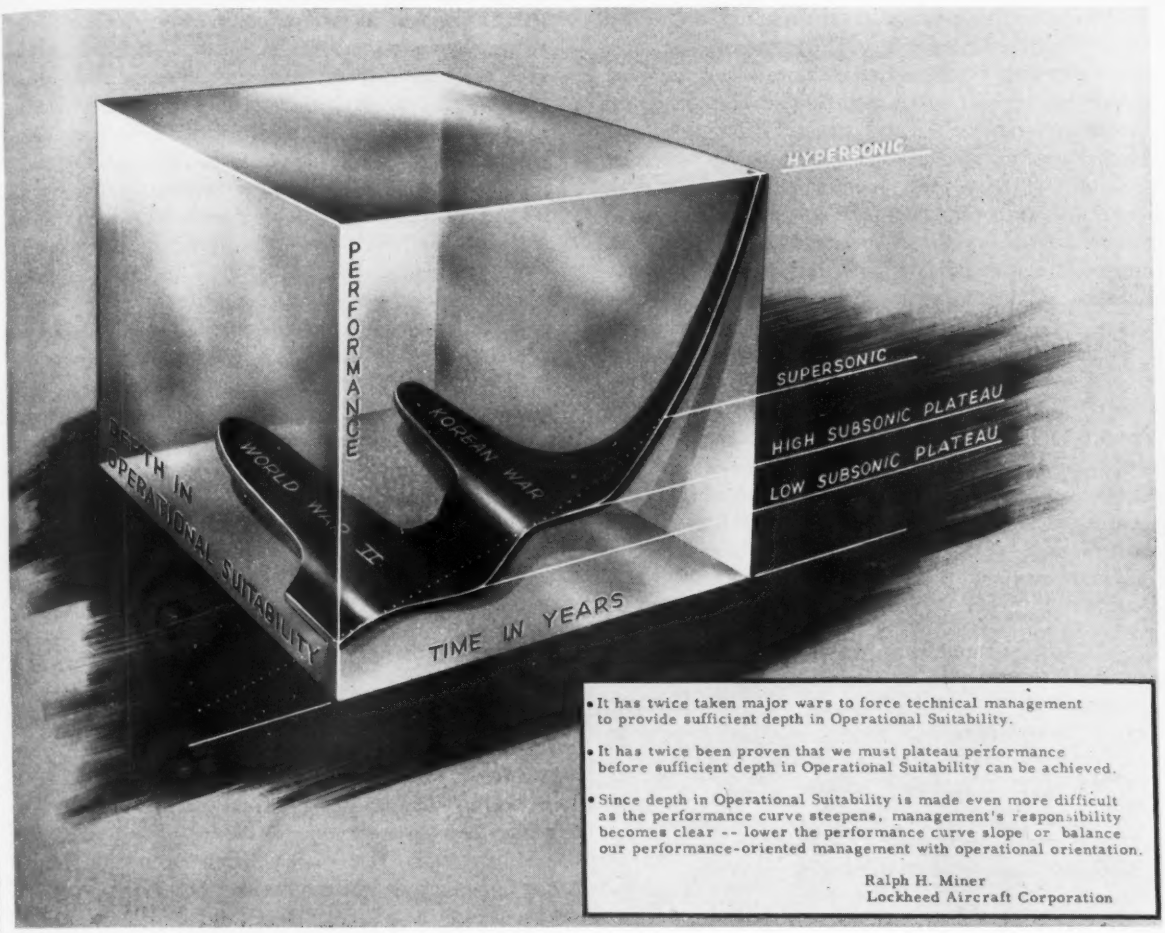
Now, to continue the building of our discussion platform, consider our third major aeronautical activity—military uninhabited aircraft. In our missile activities, it is difficult to compare "gross accident picture" with "performance regime." However, a few general observations should be sufficient for our purpose.

The missile business is fraught with a kind of dual frustration. Not only are we attempting a quantum jump to an extreme performance regime, with all the inherent material difficulties implied in this, but we are flying these machines with an absolute requirement that everything be right before leaving the ground. Yes, there are many misadventures in surface launched guided-missile operations. We should note, however, that our inordinate apprehension, both of malfunction and of the tremendous forces involved in reaching for extremes in performance, has at least netted us a near perfect safety record.

Indeed, paradoxically enough, if the missile engineer can learn to do his job without a catchall human pilot to lean on, we may well engender engineering disciplines that will be instrumental in realigning engineering policies in the inhabited aircraft field. In any case, operational stability in the missile business is still far down the road.

To summarize our discussion thus far: We have indicated in gross terms the state of three areas of aeronautical endeavor, and we have discussed three milestones in performance regimes and have indicated the state of operational stability in each regime. In short, the state of aeronautics as a whole reveals that a phenom-

* Head, Staff Engineering, Missile Systems Division.


HYPERSONIC
SUPERSONIC
HIGH SUBSONIC PLATEAU
LOW SUBSONIC PLATEAU
PERFORMANCE
KOREAN WAR
WORLD WAR II
DEPTH IN OPERATIONAL SUITABILITY
TIME IN YEARS
• It has twice taken major wars to force technical management to provide sufficient depth in Operational Suitability.
• It has twice been proven that we must plateau performance before sufficient depth in Operational Suitability can be achieved.
• Since depth in Operational Suitability is made even more difficult as the performance curve steepens, management's responsibility becomes clear -- lower the performance curve slope or balance our performance-oriented management with operational orientation.
Ralph H. Miner
Lockheed Aircraft Corporation

enal growth in performance can be contrasted with a *steady retrogression in operational stability.*

This gross situation—this growing instability in the operational arena—is a direct function of insufficient air operations consciousness in aeronautical engineering. Looking at the situation historically, we see that it is no small problem since such had been the case for over half a century.

The basic philosophy that motivated the Kitty Hawk effort has remained virtually unchanged. The approach to the problem at Kitty Hawk placed the operator, at the outset, in an incidental role. "Of course, man can fly," they said. "Da Vinci proved this; all we need is sustaining power." Sustaining power was achieved; history duly recorded. This, in turn gave birth to the credo: "We must go a little higher, a little faster, a little farther."

That was over 50 years ago. I recently attended an important aeronautical event in which a distinguished keynote speaker initiated his talk with these words: "We are all gathered here to go higher, faster, and farther . . . etc." While this limited approach to design engineering is now inexcusable, it is understandable that it is still with us. Let us, then, attempt to understand the situation so that our corrective suggestions will be incisive.

From the earliest days of powered flight up to the early years of World War II, the man in the operational arena—the pilot, the flight crewman, the ground crewman—was considered by the design engineer to be an inexhaustible reservoir of operational ingenuity and integrating skill. And, at the time, he was, indeed, just that. The operational man readily endorsed the engineer's viewpoint, for the operator was well within his potential capability. The engineer would ask him to go higher and faster, watch a few more dials, push and pull a few more handles—no strain.

The same was the case in the ground support phase of air operation. The ground support crewman's problems were not great. Tools, maintenance equipment, checkout equipment, etc., were straightforward adaptations of readily available materiel. Further, the internal density of the aircraft proper was quite low and, therefore, readily attended even by subskilled support personnel.

Year after year the engineer worked for higher performance, tossing uncorrelated operational considerations on the then-willing shoulders of the operational people. Unfortunately, this innocently established working relationship between the engineering people and the operational people gradually became a deeply

rooted engineering precedent. To amplify this point: These were the "airworthiness" years, so to speak—man reconciling a powered machine to a new medium. These were the years in which the airplane's need for greater performance, greater structural integrity, and greater aerodynamic efficiency legitimately exceeded the needs of those who operated them. This gave premature birth to a new technology. Career areas were charted, a giant new industry was launched, university aeronautical engineering courses were established. All this with no operationally oriented conceptual effort—an effort that would have checked and balanced what has now become a sort of Frankenstein technology. I say Frankenstein technology because a handful of people have attempted—thus far with little success—to stem the performance hysteria which now characterizes nearly the entire aeronautical community. In short, we are, in my opinion, enduring an aeronautical technology which is *conceptually incomplete* and desperately in need of orientation from an operational point of view.

Corrective Measures

While these measures are aimed toward attaining operational stability, they are not based on a sacrifice in performance regime. We can embrace any performance regime that is based on sound Air Technical Intelligence estimates of Soviet air strength. We shall have to pay something, of course, to achieve both performance regime *and* operational stability. This price will be both in time and in the temporary disturbance associated with appropriate policy realignment. An incisive policy realignment could, of course, reduce the time loss to a point where it would appear insignificant in the light of increased effectiveness.

I am going to suggest that in the design engineering arena we subjugate our performance thinking to a new mandate—operational suitability. I shall attempt to illustrate a concept in which the directive force in design engineering is "air operations," rather than "performance," consciousness.

The climate for introducing such a concept has never been better. I, for one, have been encouraged not only by the modest successes associated with experimenting with this concept in my own company but by the trend on the part of both industry and the universities at large to back away and examine critically their traditional engineering practices. I believe they are looking for a new and more penetrating aeronautical engineering philosophy. The following is therefore suggested:

To begin with, an operational suitability staff reporting to the Director of Engineering would be established. Initially, this office would have both staff and line authority and would serve the Director of Engineering as a device for maintaining full spectrum cognizance of all operational considerations that should influence the design.

This does not suggest any immediate modification of the remainder of the organization. Classical functions such as aerodynamics, structures, propulsion, electronics, systems analysis, and engineering test remain unchanged. We have merely introduced a situation wherein none of these classical functions moves toward problem resolution without authoritative monitoring by the Director of Engineering's operational suitability staff.

What, then, are the skills found in the operational suitability staff which are not found in the classical areas or, when found in the classical areas, are not at effective levels of authority? This staff is manned by senior engineers and scientists who have placed their classical technical background in a subservient role and are now responding to knowledge and skills acquired outside of the immediate design engineering arena. These skills have been acquired in the field of actual military operation of all types of inhabited aircraft and guided missiles, as well as in the field of military operations research. Some of the system skills from these two broad areas are intelligence, reconnaissance, defense, tactical air, strategic air and training, logistics, crew systems and human factors, communications, air traffic control, navigation, meteorology, geophysics, ground support equipment, statistics, economics, social sciences, and others.

How do we integrate this imposing array of skills at design board level? First, we need leverage on the engineer, a *modus operandi* that is impersonal and completely objective. We want the engineer to appreciate not only that he is being helped but that, indeed, he cannot forever wiggle off the hook on the grounds that classical precept has been violated.

The *modus operandi* of the operational suitability staff is to ensure that each act of design takes place in an "operational engineering laboratory" and that all designs reflect due consideration of "operational time and motion" limitations. *Time and motion in the user's operational environment*—this is the key and, in fact, the *missing conceptual link* in maturing our aeronautical technology.

At this point, let me illustrate what I mean by placing a mature, traditionally backgrounded engineer at the preliminary design board. Let us assume that he is going to design a prototype of a new 1,000-knot, all-weather interceptor—an interceptor which will operate in the *total* weapon system environment as modeled in the operational engineering laboratory. Remember that, while the engineer will have all the assistance he needs, this assistance will be strictly air operations oriented. All major design decisions—and most of the detail decisions, for that matter—will be impersonally referred by time and motion in the operational environment. With this in mind, let us consider the highlights of a conceptual design effort.

First, from his many years of experience and design judgment, our engineer drafts a qualitative sketch of the geometry of the overall airplane. His first sketch is a roughhewn cut, so to speak, of an all-weather

interceptor that will meet performance requirements. Now, traditionally, we would find the aerodynamics department rushing in at this point to shave our roughhewn cut of an airplane down to a sleek, maximum performance envelope. We have agreed, however, that we want operational suitability just as much as we want performance, and you cannot have both if aerodynamic refinement occurs early in design. So, we direct our engineer to make an immediate departure from tradition.

Drawing on the skills in the operational suitability staff and utilizing the facilities of the operational engineering laboratory, our engineer will, in effect, "fly" his roughhewn design in making a time and motion schedule for each succeeding design refinement.

One of the design parameters our engineer must have in the back of his mind all the way through the design effort is aerodynamic stability. Top performance and *operationally suitable* aerodynamic stability are not always compatible. Therefore, since stability will be a major influence in the initial shaping of our roughhewn design, our first time and motion effort will be aimed toward an appropriate aerodynamic stability parameter.

Since this is our classically backgrounded engineer's departure from the traditional design approach, the operational suitability staff will first guide him in contrasting the company's experimental test environment with the military user's operational environment. Since the time and motion factor has never been critical in the company's flight environment, this comparison will give the engineer a feel for the scope of time and motion as a prime design factor. The factors in this comparison may be listed as follows:

(1) The company's experimental test pilot has a flight scramble time of anywhere from 3 hours to 3 days. . . . The military pilot has a flight scramble time of only 3 min.

(2) The company pilot taxis out singly with much time and room for lateral motion on the taxiways. . . . The military pilot taxis out with other fighters, hurriedly, with little time and highly restricted lateral motion on the taxiways.

(3) The company's experimental test pilot swings onto a 7-mile runway after spending ample time getting ready for take-off; ceiling and visibility are unlimited and the sun is shining brightly. . . . The military pilot is cleared with virtually no readiness time onto a 1-mile runway; ceiling is 500 ft., visibility 1 mile with light rain, and it is night.

(4) The company pilot, with a physical dexterity and mental facility born of several thousand flying hours, leisurely takes off into the bright sunshine. . . . The military pilot, often with only a few hundred hours of experience at his disposal, charges off into the night and, with no time for contemplation, is immediately engulfed in the overcast.

(5) The company pilot is at 10,000 ft., 7 miles of runway lie in plain sight over his left shoulder. "What's this? Tip tanks not feeding? Well!" He will have to abort the flight. A leisurely pass over the field, a wide sweeping pattern—"No use crowding the pattern," he says to himself. "This isn't necessarily a delightfully stable thing with landing gear, fairing doors, and stuff hanging out the bottom. Better not let too much time go by on gear extension either—that aft retracting nose gear is a little slow on extension." So, with a long, straight-in approach and adequate speed to work with, a casual landing is made half-a-mile down a dry, 7-mile runway. This is a flight in the company's test environment. . . .Let us look in again on our military pilot. He has just broken out on top at 10,000 ft., the moon is shining brightly, and he has drawn a deep breath of relief, for he plans to use a clear-weather alternate base after he completes his mission. "What's this? Tip tanks not feeding?" The mission will have to be aborted. At this point it is unfortunate that a minute is only 60 sec. long, for our military pilot will now be asked to do more things per minute than he is *consistently* able to do. And he is flying only a subsonic jet fighter.

Since he is aborting the flight under night-instrument conditions, his first step is to continue his climb-out on a predetermined course. He contacts the tower, reports conditions, and requests landing instructions. He then handles the following sequence of events: He contacts approach control, assimilates instructions, requests ground controlled approach, intercepts outbound track, and turns to outbound heading. He levels off at 20,000 ft., trims aircraft, reduces power. He turns left 90°, rolls into 270° right turn, and intercepts inbound track. At marker he applies 60 per cent power, contacts approach control, and assimilates further instructions. He extends dive flaps; at 180 knots, he puts wheels down, puts flaps down, and establishes 160-knot descent. At 10,000 ft. he starts 180° turn, contacts approach control, and assimilates instructions. He contacts traffic controller and assimilates further instructions. He puts gear up, flaps up at 1,000 ft. above desired altitude, dive flaps in at 200 ft. above desired altitude. He levels off, adds power, intercepts inbound heading, turns to heading given by traffic controller. He turns downwind, executes prelanding check: gear down, part flaps, green lights, pressure up. He turns onto base, contacts final controller, lets down 500 ft. He turns onto final, adjusts to descent speed, receives final instructions. At glide path, he reduces power, drops nose, makes corrections in glide slope, makes corrections in azimuth. On sighting field, he turns on landing lights, extends full flaps, extends dive flaps, establishes sink rate, rounds off late, touches down hard, and stops gingerly on the far end of the wet runway. This time he makes it. Fortunately, he gets away with several errors which occur as natural by-products of a "time saturated" operational environment.

To summarize the flight: In the brief period of time allotted for these fifty or so events, our military pilot will have checked his instruments at a rate of nearly 200 per min. In the presence of rain, air turbulence,

and darkness, he will have interpreted these readings and applied control forces for definite corrections in flight path and attitude at a rate of about 50 per min. He will have responded to, actuated, or concerned himself with over 200 cockpit instruments, indicators, levers, and switches found in this particular jet aircraft. At the point he stops his aircraft and clears the runway, he will have made over 1,000 major and minor decisions and 2,000 lever, switch, and control actuations or deflections, all compacted within an *uninterruptible* segment of time, at night and in weather.

Following this comparison of company and military flight environments, our engineer is now pretty well conditioned to talk about the 3,000 Air Force accidents that resulted from unsafe acts of pilots. He is advised that these 3,000 accidents occurred only since January, 1954, and that most of these accidents occurred under conditions far less difficult than those just described. Since our first design refinement step is to generate an adequate aerodynamic stability parameter, our engineer is particularly impressed with the fact that, among the cause factors, the highest percentage of accidents occurred as a result of incomplete piloting in the landing pattern. Obviously, a result of time saturation. We are making headway. Our design engineer is now asking operational questions. He wants to know why we placed emphasis on "night" and "weather" in our comparison of operating environments. The operational suitability staff hastens to point out that each act performed by the pilot at night requires an extra increment of time. If low ceilings and rain or snow are present, we add still another increment of time for each act, pointing out that night and weather factors induce a significant perceptual lag in the human perception-response time sequence. While these extra increments of operational time are often in seconds and microseconds, our flight environment discussion tells us that these time increments are cumulative at a terrific rate. In short, the military pilot must have at his disposal, among many things, a degree of inherent aircraft stability that will see him through a staggering burden of operational decision and execution.

Our design engineer is convinced. We have authoritatively and painstakingly educated him to the true depth of his design problem.

He now introduces into our hypothetical design of a new all-weather interceptor a degree of inherent stability that will free the pilot of having to forfeit an excessive portion of his precious operational time to the preservation of flight equilibrium. Our engineer is now beginning to understand the absoluteness of time and motion in the operational environment. He begins to appreciate time as a solid, so to speak—*an operational time block capable of containing only a limited number of orderly events*. In designing to a higher performance regime, the analogy of time as a solid tells the engineer that significant increases in rate of climb and speed actually seek to compress the operational time block. The operational time block, of course, *cannot be compressed*—it can only be relieved. In other words, since our current design practices are without operational time and motion control, each succeeding generation of higher performance aircraft imposes upon the military pilot more things to do and less time to do them—and we are already virtually at saturation. Go a step further in our study of "operational time" versus "aerodynamic stability," and it becomes clear that each increase in performance regime carries with it an engineering obligation for an increase in inherent aerodynamic stability. Since the opposite of this is current practice and since I do not wish to skid off into a power requirement argument at this point, let us for now set aside this aspect.

As discussed, we have designed into our hypothetical interceptor an *operationally suitable* level of inherent stabilty, a level of stability that can be introduced only during the conceptual phase of design. Such a level of stability would not be feasible were we to attempt to introduce it as a result of Air Force operational suitability tests conducted later in the program.

At this point we have fairly well established the basic shape of our new 1,000-knot interceptor. To the distress of the aerodynamics department, we added, among other things, a few feet of wing span in achieving our high degree of inherent stability. The aerodynamics department would like to argue this point, but we are not yet ready for aerodynamic refinement. We still have several major design decisions to make, decisions which, again, will be controlled by operational time and motion.

Now that we have a feel for time and motion as a major design influence, I shall cover briefly several design considerations and then offer a few concluding remarks.

Landing gear design, while a somewhat more localized consideration than stability, is nonetheless a major factor in refining still further the basic shape of the airplane. We earlier referred to the military pilot's short scramble time, short taxi time, and confined taxiways. We also implied the hard, runway-consuming landings to be associated with rapid-fire pilot decisions on a night-weather time and motion schedule. In translating these time considerations into a landing gear design that will further relieve the operational time block, we first examine, from January, 1954, over 300 Air Force accidents that occurred as a direct result of failure or malfunction of the landing gear system.

Starting with the nose gear, detail study indicates that excessive operational extension time on aft retracting nose gears has occasioned many of these accidents. We decide immediately that in the design of our new interceptor, the nose gear should retract forward. We also decide on high ratio nose gear steering in order to facilitate short-time, accident-free, formation taxiing.

We note further that nose gear failures nearly double the failure of main gears. Of course, we immediately agree with the structures department that we cannot

pay the weight penalty that would be associated with a failureproof landing gear; but we are not asking this. We ask our engineer only that he design a nose gear that will fail no more often than the main gear and that we stop treating the nose gear as an auxiliary gear—which it is not!

Next, brakes, wheels and tires, and fairing doors. Our Air Force accident record places inadequate fairing doors, inadequate tires, and inadequate brakes at the top of the cause factor list in landing gear accidents. So our engineer designs into the landing gear system *a reduction in the operational time* required to stop the airplane. Notwithstanding such primitive devices as drag parachutes, this still means larger wheels, tires, and brakes.

Yes, an operationally adequate design job on the landing gear system will increase the overall bulk of the gear, and, again, we disturb the aerodynamics department. However, we are still not quite ready for aerodynamic refinement. So, with our need for larger wheels, tires, and brakes; wide tread, simplicity of design, supersimple fairing doors; and minimum extend-and-lock time, we mount a forward-retracting main gear in flush-mounted external-stores pods.

At this point, we check with our design engineer's assistant who, with the help of the operational suitability staff, has been working out fuselage space requirements. Again, as in the preceding examples, operational time and motion was the referee; military operational records the design catalyst. He has selected the propulsion system components and has determined overall functional system space allocations, as well as cockpit space allocation.

Incidentally, I passed rather lightly over cockpit design. While this is one of my favorite subjects, it is one of the less difficult time and motion design problems. I therefore elected not to risk narrowing the scope of our time and motion concept. The time and motion technical decision process is applicable not only to details but to major decisions on total weapon system concepts. At best, only the highlights of one element of a total problem could be described here.

Thus, for purposes of this description, we have completed the basic design of our new 1,000-knot interceptor. More than this, the design has been *conceptually secured on an operational time and motion basis.* With this, we turn the design over for aerodynamic refinement and other classical treatment. The operational suitability staff at this point assumes a monitoring and support role.

Conclusion

I suggest we observe the general reaction to last spring's reports of how the Russians have shortened the development cycle far beyond America's expectations. I shall not attempt to speculate on Soviet technology. I shall, however, express concern over the technical community's reaction to this new point of view on the threat. More research was the immediate cry. But what kind of research? Performance research only! Boundary-layer control, high-temperature effects on structures, specialized power plants, high resolution radar, solid-state physics, and the like—all important, yes, but grossly inadequate insofar as realignment of the development cycle is concerned. No significant research has been aimed toward the conservation of operational and engineering manpower or toward greater orderliness in the technical decision process.

Disturbingly enough, this is only too indicative of the urgency of the concept outlined here. The pure performance emphasis that permeates our aeronautical technology should not continue.

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A compromise approach to the question of analog vs. digital methods of computation.

Operational Digital Techniques for Special Purpose Computers

R. N. Nicola*
The Newton Company

Introduction

Operational digital is a term used in referring to the use of unitized pulses to represent variables in control and computational systems. Normally, in these systems, a.c. or d.c. voltages are used as analogs of a physical quantity, thus giving rise to the term "analog" computers. Operational methods are in essence analog techniques wherein pulses are used to convey a certain value of the quantity to be synthesized. The advantages of such a method are obvious. The use of unitized pulses makes it possible for a system designer to select a value to be assigned to each pulse. This value can be chosen for the appropriate system resolution. For example, in a system where velocity is to be used, a pulse can be chosen to represent a unit of length, say 0.1 miles. Then, to instrument a velocity of 100 m.p.h., a pulse rate of 1,000 pulses per hour can be established, and all the necessary manipulations required can be performed on this pulse rate. The obvious requirements to make use of such a method are the components to add, subtract, integrate, etc., or perform other computations on the variable. In the discussion to follow, the various components are described.

Several advantages are realized in using the techniques described here. The most important, of course, is the possibility of maintaining accuracy throughout a system. Once a system accuracy has been chosen, the number of digits to be used throughout the system can be chosen for that accuracy. This leaves the accuracy independent of the components within the system.

By the very nature of a pulse system, integrators can be constructed to have any range while maintaining their resolution. In other words, there are no "dead bands" at low levels of integrated value such as is common in various analog devices. Each pulse arriving at the integrator contributes the same amount to the integrated value independent of the status of the integrator.

Important in maintenance and checking is the ability to determine easily the system operation. Since pulse rates are flowing within the system, the main test equipment required is an Eput meter or its equivalent. Visual displays on neons or other devices are easily incorporated for quick evaluation of system operation.

Needless to say, one of the most important considerations in choosing a method of accomplishing a given task is the cost in equipment and dollars. This consideration is particularly important when a system such as described here is to be used in place of a more conventional analog method. There is no doubt that a crossover in price exists between these operational digital techniques and analog methods. The variable involved in determining this crossover is the desired accuracy. There is, of course, no well-defined point where such a crossover can be placed, but it is the feeling here that these digital methods become competitive at accuracies on the order of 1 per cent and no doubt at 0.1 per cent.

One area that seems to be taking on a greater importance is that of recording many data involved in computers, control processes, etc. This recording ability is particularly desirable in training devices where a training situation must be recorded for future study and evaluation of a trainee's performance. Using the unitized pulse concept, the recording can be accomplished on magnetic tapes or drums, typewriters, etc., so that playback is not a problem as compared to the use of analog systems and their associated recording methods. In many instances, it is possible to record a particular situation for training purposes so that this situation can be played back for presentation of complex training exercises.

There are disadvantages in using these techniques, probably the most serious one being the very fact that all variables are permitted only discrete steps which in some instances is unsuitable for human consumption. This is true since most of the quantities represented in these applications are smooth and continuous by nature. There are two general ways of overcoming this disadvantage. The first is to choose steps so fine that they are beyond human perception; the other is to use some smoothing action on the particular output. Generally speaking, no consideration of these discrete steps is required if the data are to be used for something other than a displayed quantity.

One feature that makes these techniques directly competitive with analog methods is their ability to

* Vice-President.

compute in real time. The disadvantage of using digital computer techniques is the need for a great number of repeated calculations in which data are transferred to and from memory and arithmetic units, thus losing the real time concept. In operational digital, the data flow is exactly that of an analog mechanization in that analogous time constants can be built in and scaled if desired. There is no memory device nor arithmetic unit as such.

The logical design of a system is also exactly that used in pure analog instrumentation. A designer need only know the nature of the various components to design a system from a logical point of view.

The discussion to follow is (1) an explanation of some of the various components presently available and (2) a discussion of some applications of these techniques.

Basic Components

Pulse Sources

The first requirement for using unitized pulse systems is a source of pulses for use in various places in the system. Obviously, any form of oscillator may be used. In many instances, when a high degree of accuracy is required, a crystal oscillator can be used. At low frequencies, tuning fork oscillators are useful. In some instances, for extremely slow pulse rates, special timing motors can be used to yield pulses with extremely long periods.

In many cases, a variable pulse rate is required. There are two basic ways to achieve this. One way is to make the actual oscillator frequency vary, while the other is to select the proper combination of a previously generated pulse rate.

There are several methods of making variable frequency oscillators. One method is to use an RC phase shift oscillator and a variable resistor to change the frequency at which the phase shift is 180 deg. This variable resistor can be a potentiometer or a vacuum tube using plate resistance. Wein bridge oscillators are also useful in this application. Another extremely useful variable oscillator is one using a tank where the inductive element in the tank is varied by changing the current through it. One commercial device available is the Increductor.

The use of selected combinations of fixed pulse rates is accomplished by means of a binary multiplier, as described in the following discussion.

Binary Multipliers

The most useful component in systems such as those to be considered here is the binary multiplier. The logical structure of such a device is shown in Fig. 1. The inputs to this unit are a frequency label V and a parallel binary number labeled X. The frequency is introduced into a magnetic binary counter shown with seven stages. The outputs of each of the seven stages is a pulse rate labeled as $V/2$, $V/4$, etc. These pulses are time separated from each other. Each of the pulse lines are led into gates G, which are open or closed as dictated by the parallel binary number X. For example, if the number X were 5/8, then the pulse rates $V/2$ and $V/8$ would be passing through the appropriate gates to the output. The output is a single line onto which are mixed the various selected pulse rates. The mixing is accomplished using a single diode from each line into a common load resistor. The details of the simplest gating method are also shown in Fig. 1.

As shown in Fig. 1, seven stages are used so that any product between 0 and 1 can be obtained with a precision of 1 part in 128 as the worst case. If a greater precision is required, more stages can be added to the magnetic counter, and of course more digits must be made available in the quantity X.

The counter, of course, is the device that limits the maximum pulse rate that can be used. At present, magnetic binary counters are available up to pulse rates of 1 mc. Above this rate, a few stages of electronic counter can be used for the high-frequency front end stages and the magnetic type for the remaining stages.

Binary Divider

Once a multiplier is available, a divider can be constructed by using an implicit solution. Fig. 2 indicates the block diagram of such a divider. The desired quotient is X/Y. In this case, X and Y are shown as parallel binary numbers. Using binary multipliers as previously discussed plus a forward-backward register, the desired solution can be instrumented.

It is interesting to consider the transient behavior of such a closed loop system. The value $Z(t)$ at any time in the forward-backward register can be written

$$Z(t) = \int_0^t \frac{Xf}{2^n}\,dt - \int_0^t \frac{YfZ(t)}{2^n}\,dt \qquad (1)$$

where n is the number of binary digits. Taking a derivative, Eq. (1) can be expressed as

$$\frac{dZ(t)}{dt} + \frac{Yf}{2^n}\,Z(t) - \frac{Xf}{2^n} = 0 \qquad (2)$$

The solution of Eq. (2) after solving for the general constants of integration assuming at $t = 0$, $Z(t) = Z(0)$, is

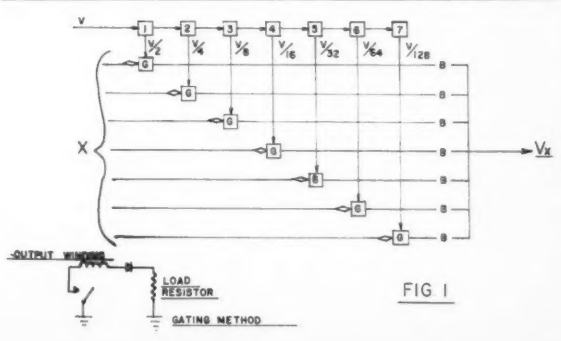

FIG 1

BINARY MULTIPLIER BLOCK DIAGRAM

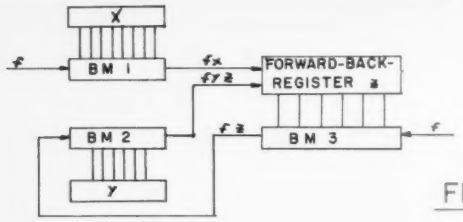

FIG. 2

BINARY DIVIDER

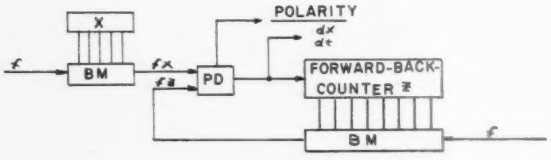

FIG. 3

$$Z(t) = X/Y\left\{1 - [1 - Z(0)]\, E^{-\frac{Yf}{2^n}t}\right\} \qquad (3)$$

As was obvious by the form of the differential equation, this response is mathematically identical to the charging of a condenser which can have some initial charge on it. The equivalent time constant is, from the exponential of Eq. (3), $2^n/Yf$.

From this it is seen that the equivalent time constant can be reduced by increasing the frequency but is increased by increasing n, the number of digits used.

Integrators

In a great many instances, the process of integration is required. In the case of unitized pulse methods, integration is simply the accumulation of all incoming pulses. These pulses of course must also have a polarity associated with them to indicate an increase or decrease of the integrated quantity. This process then is simply a summing process carried on over a period of time.

An integrator can consist of several forms depending on the desired output. A forward-backward register as shown in the divider is essentially an integrator. In the case of the divider, it is an electronic reversible counter. The output then is a parallel binary code. A precision resistor network can be used to convert the digital data to a voltage.

In some cases, a shaft position must be created as the output. In such instances, the pulses are fed into a rotary solenoid which turns the output shaft the equivalent value of one pulse. The solenoid structure is such that the output shaft is detented and thus must assume discrete steps in the same sense that a counter assumes only discrete values.

Obviously, the conversion from the shaft position to a voltage can be accomplished using a potentiometer.

Mechanical counter displays are easily had using these rotary solenoids. Again, since the inputs to these counters are discrete, the display counter digits will increase or decrease in the same steps.

The electronic counter integrator is adaptable to high pulse rates, while the shaft position output is limited to about 60 pulses per sec. In effect, this says that a maximum change of 60 least significant digits per sec. is permissible, therefore limiting the speed of response for high accuracy systems.

Differentiation

As in analog methods, if a closed loop type of integrator is formed, the input to this integrator must then be the derivative or rate of change of the involved variable. Fig. 3 indicates the method of forming the derivative for the quantity X. If X had been directly available as a pulse rate, the associated binary multiplier would not be required.

Obviously, as in the divider, the forward-backward counter will come to its steady state when its content Z is equal to X. This then is a frequency meter or a pulse rate to parallel binary converter. This conversion is often required in computing systems for display purposes or for further computation.

It should be pointed out that this forward-backward counter can be an electronic register or a mechanical forward-backward integrator again dependent on the incoming pulse rate.

Resolvers

In almost all control systems, there arises a need for generating the trigonometric functions sine and cosine of an angle presented as a shaft position. There are several methods of generating these functions from this input shaft.

One method is the use of a mechanical linkage with a linear converter driven from a rack. This converter can be a linear potentiometer, or it can be a linear encoding disk which has some digital code as its output.

Another method is the use of an encoding disk which has the correct code for the function built in. In this way, the mechanical equipment is not required, but added complexity in the disk increases its cost.

Once the values of sine or cosine are available as parallel numbers, it is only necessary to use this number with a binary multiplier to create a pulse rate proportional to the desired function.

One other method of generating these common functions is the use of an implicit solution. Fig. 4 indicates a method of generating the sine and cosine functions of a continuously rotating shaft such as a radar antenna. Some form of pickup is made available such that at each increment of angular rotation a pulse is generated to represent the change in the angle X. These generated pulses are introduced into binary multipliers as shown. The end result is the implicit solution of the two equations shown in Fig. 4.

To ensure no accumulative errors, the rotating member can have another track for generating pulses at 90

deg. intervals. At each of these intervals, the sine and cosine registers are cleared to either 1 or 0 as the case may be.

Function Generators

Generation of various functions can be accomplished in several ways. One common way is to use functional potentiometers or function discs when the input variable is a shaft position.

Another extremely useful function generating device is a diode matrix. Of course, this matrix requires digital input and yields digital output. In many instances, it is sound to perform a linear conversion to digital form and then use a diode matrix to generate the desired function.

The output of a diode matrix can be directly used to perform the gating in a binary multiplier.

Synchronizing

Often in pulse circuitry it is desirable to synchronize a randomly timed pulse with a standard or clock pulse. This implies a device that receives a pulse at a random time and stores it until the clock pulse reads it out.

This synchronizing action can be had using one magnetic core and one double triode tube.

Converters

One important area in the use of digital systems is that of conversion from analog to digital, and the reverse. In order to justify the use of digital systems, the cost of making input data available in digital form must not be elevated beyond reason.

Several methods exist for converting from shaft positions to digital form. Some of these have already been discussed above, in particular the use of encoding discs. This method is generally the most straightforward and usually is economically justifiable.

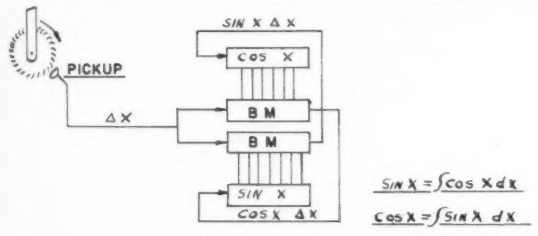

FIG 4

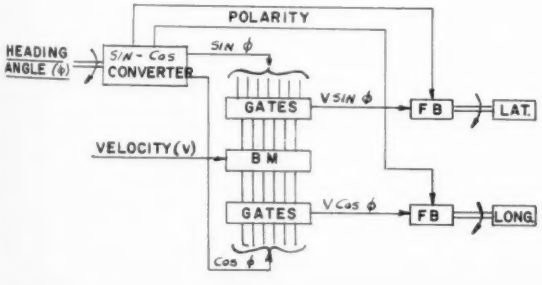

FIG 5

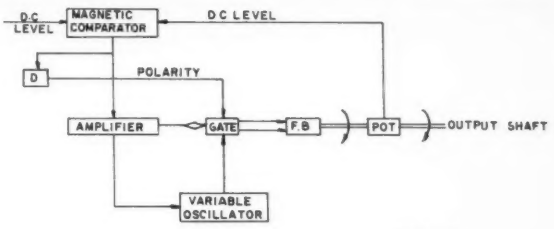

FIG 6

Other methods are the accumulation of incremental pulses as described in the considerations of the sine-cosine generator.

The conversion from d.c. voltage to digital is often required, and many equipments have been proposed and used. In general, it appears that a closed loop system with a comparator is the most versatile, as well as the most accurate and reliable. In this type, a digital register is used to contain a digital representation of the voltage. The register contents are converted to a voltage so that this voltage can be compared to the voltage to be measured. The results of the comparison are used as an error signal to actuate the digital register in such a manner as to cause the error to approach zero.

It is important to note that in using the closed loop converter, the conversion from digital to analog is easily accomplished.

Applications

The systems and components described above present no severe limitations as to where they may be applied. The discussion following is intended to demonstrate some successful applications of the techniques and components previously discussed. In some instances, the applications have been in air-borne equipment, while others have been in high-temperature test facilities.

Navigational Computation

A simplified navigational computer is shown in Fig. 5. This demonstrates the basic quadrature multiplication and then integration as required to display present position. The blocks labeled *FB* indicate a forward-backward mechanical drive for display on standard counters. One advantage here is the long distance possible for the lines to the display point. These lines need only carry a pulse of current whenever the counter must turn one increment, and the impedance is of no concern since it is very low to any pick up noise.

Digital Servo

The situation often arises where a shaft position is to be created as the direct representation of a d.c. voltage level. Obviously, there are many ways to achieve this desired instrumentation. The diagram of

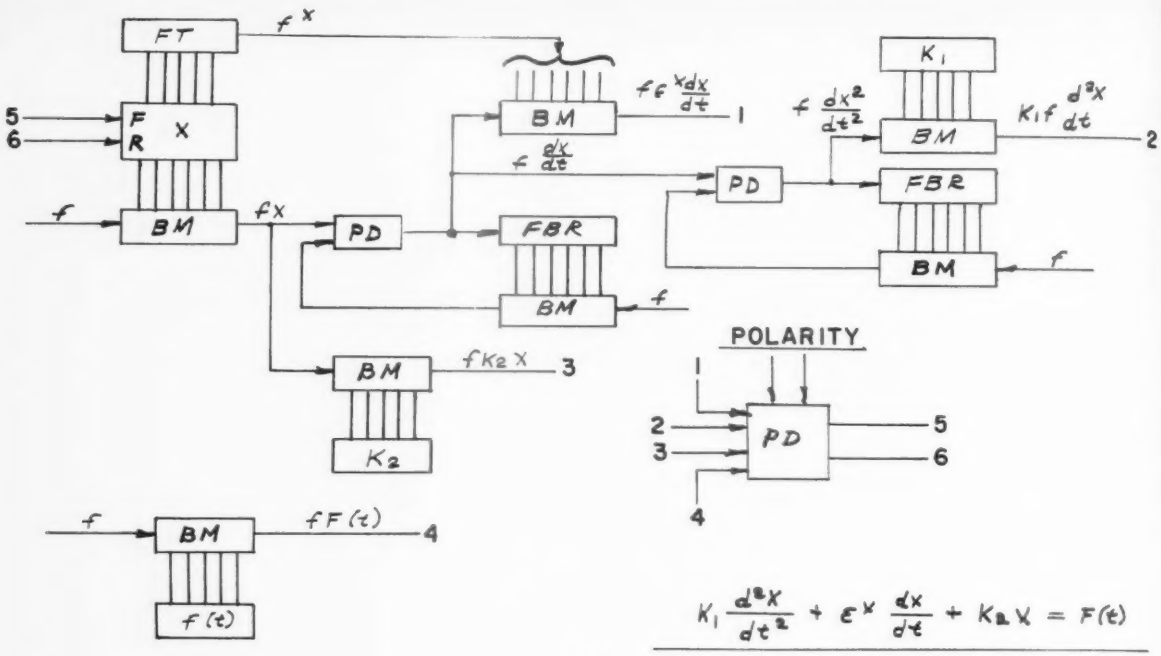

FIG. 7.

Fig. 6 indicates a method of using proportional control with operational digital methods. The key to the entire loop is the magnetic comparator. This device is an extremely stable and sensitive comparator which yields a constant frequency whenever the two input d.c. levels are not equal. The phase of this output signal indicates which d.c. level is larger. The phase is detected in the block labeled *D* whose output is used to control the polarity of the reversible mechanical drive *FB*. The amplitude of the error signal is used to open a gate *G* and to control the frequency of the oscillator. Whenever a large error exists, the frequency is increased to increase the rate of response of the loop. As soon as the comparator output falls below a certain level, the gate closes, and the frequency drops to its lowest value and the loop is stable.

Footage Counter

Many industrial applications present themselves wherein it is desirable to display accurately the footage of material passing a certain point. In many of these instances, it is necessary to count shaft revolutions and apply a scale factor to the number of revolutions to display a count in feet, inches, yards, etc.

This can be easily accomplished by using a pulse pickup from the shaft and a binary multiplier to apply the scale factor. By the use of either a prewired switch or an encoding disk, any desired scale factor can be applied.

Differential Equations

Since the components involved in the techniques described here are essentially the same components as found in analog systems, the solution of differential equations are straightforward. In fact, for purposes of differential equation solutions, a plug board type of computer is easily available. These techniques have been employed to some degree on digital differential analyzers.

A simple block diagram illustrating the solution to a particular nonlinear differential equation is shown in Fig. 7. The quantities involved are all components as described in the preceding discussion. For use in applications such as operational flight simulators, this type of instrumentation with a storage device and programing equipment would be applicable.

Conclusions

In summary, the effort here has been to describe what is believed to be a rather different approach to some quite common computer applications. In general, it appears that the techniques described are somewhat of a combination of analog and digital methods. It is hoped that these techniques can be submitted as a compromise approach in the running battle between analog and digital systems.

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IAS News

(*Continued from page 40*)

ducing hazards of combat through revolutionary training methods which he instigated and perfected, he headed the Division of Special Devices and later was Deputy Chief of the Office of Naval Research.

In 1944, Admiral de Florez received the Collier Trophy "for his contribution to the safe and rapid training of combat pilots and crews."

Guggenheim Fellowships Open

The Daniel and Florence Guggenheim Foundation, New York, has announced it will select candidates by April 1 for its 1956 Fellowships in Jet Propulsion and Flight Structures. Eighteen to 20 Fellowships are awarded annually for graduate study at the Jet Propulsion Centers established by the Foundation at California Institute of Technology and Princeton University and at the Institute of Flight Structures established at Columbia University. Stipends range from $1,200 to $2,000, plus tuition (less the amount provided by veterans' educational benefits).

NEWS OF MEMBERS

▸ **Richard S. Boutelle** (M), President of Fairchild Engine and Airplane Corporation, has been named to the Executive Committee of the National Aeronautic Association.

▸ **James H. Doolittle** (HF), Vice-President of Shell Oil Company, has been reappointed to the National Advisory Committee for Aeronautics by President Eisenhower.

▸ **Paul Lieber,** Professor of Geophysics in the Department of Geology, Rensselaer Polytechnic Institute, has opened a program of research for the Air Force Office of Scientific Research, Air Research and Development Command. The study concerns the extension and application of variational principles for calculation of real flows.

▸ **William P. MacCracken, Jr.** (M), Washington, D.C., Attorney, has been appointed Chairman of the Executive Committee and General Counsel of the National Aeronautic Association.

▸ **John F. Victory** (M), Executive Secretary of the National Advisory Committee for Aeronautics, has been re-elected a Vice-President of the National Aeronautic Association.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Don C. Ballentine (TM) has joined Convair-San Diego Division, General Dynamics Corporation, as a Research Analyst in the Experimental Flight Test Group. Formerly, he was employed as an Aeronautical Research, Development, and Design Engineer in the Aerodynamics Laboratory of the Navy's David Taylor Model Basin, D.C.

Thomas F. Bergmann (M), formerly a Senior Sales Representative, has been promoted to Export Sales Manager of Lockheed Aircraft Corporation. Before joining Lockheed last year, he was Sales Manager of Wright Aeronautical Division of Curtiss-Wright Corporation.

Walter W. Bird (M) of Cornell Aeronautical Laboratory, Inc., has formed a company to develop and manufacture air-supported structures such as the radomes and portable blown-up fabric buildings used

Necrology

Willard J. Amick

Willard J. Amick, TMIAS, a Flight Test Engineer with Douglas Aircraft Company, Inc., was killed October 27 in the crash of an A3D twin-jet bomber near Lancaster, Calif., during a test flight.

Mr. Amick, who was 29, was a graduate of the University of Michigan and a member of Tau Beta Pi. Before joining Douglas-Santa Monica in 1949, he had been a civilian engineer at Wright-Patterson AFB and an engineer with Curtiss-Wright Corporation at Columbus, Ohio. He is survived by his father, J. H. Amick, of Detroit.

Ralph S. Damon

Ralph Shepard Damon, 58, President of Trans World Airlines, Inc., died of pneumonia on January 4. He had just been elected the American Honorary Fellow of the Institute for 1955.

Mr. Damon, who spent his entire business career in aviation, was graduated *cum laude* from Harvard University in 1918. He learned to fly in the Army Air Corps before he drove an automobile.

Joining the Curtiss Aeroplane and Motor Company in 1922, he soon became Factory Superintendent and took part in developing several notable airplanes, including the Curtiss Robin and Thrush, the Curtiss-Wright Junior, and the Condor, the first all-sleeper transport. He was named President of the Curtiss-Wright Airplane Company in 1935.

In 1936, Mr. Damon joined American Airlines, Inc., as Vice-President for Operations. Shortly before World War II, he assumed the Presidency of Republic Aviation Corporation at the urging of the Government. He later returned to American Airlines and was elected President in 1945. He moved to T.W.A. in 1949.

A member of the IAS for more than 20 years, Mr. Damon served three terms on the Council. He was a member of the National Advisory Committee for Aeronautics and Chairman of the Board of Trustees of Clarkson College of Technology.

A tireless traveler, he flew more than 100,000 miles a year on business and had met most of T.W.A.'s employees personally.

Mr. Damon, who lived in Garden City, N.Y., is survived by his wife, two sons, and two daughters. Burial was in Concord, Mass.

Harold W. Peterson, Jr.

Harold W. Peterson, Jr., MIAS, an Engineering Test Pilot with Piasecki Helicopter Corporation, was killed January 5 when the Piasecki YH-16A, giant turbine-powered tandem-rotor helicopter, crashed during a test flight.

Mr. Peterson, who had been an Air Force pilot for 10 years, flew P-61 and P-38 fighters in the Southwest Pacific during World War II. After the war, he was assigned to the Air Research and Development Command as an Experimental Test Pilot at Wright-Patterson and Edwards Air Force bases. His flying time included 1,000 hours in 14 types of rotary-wing aircraft.

Mr. Peterson, who was 35 years old, lived in Media, Pa. His wife and two children survive.

U.S. TRAINS WORLD'S BEST JET PILOTS AT LOWEST POSSIBLE COST

USAF T-33A/U.S. NAVY TV-2 JET TRAINER

NINE OUT OF TEN U.S. MILITARY JET PILOTS HAVE BEEN TRAINED IN LOCKHEED JET TRAINERS

FLEXIBILITY OF LOCKHEED JET TRAINERS ENABLES MILITARY PLANNERS TO ACHIEVE MAXIMUM ECONOMY!

Planes, like automobiles or sewing machines, can be manufactured at less cost in large quantities. This is particularly true of military aircraft, due to their inherent complexity and the exacting construction requirements of the armed forces.

U.S. military planners decided almost ten years ago to standardize on *one* jet trainer—adaptable to the pilot-training requirements of *all* branches of the armed services. Lockheed's jet trainer was an ideal choice, because its advanced basic design could be kept militarily up to date at minimum expense. The saving on over 4,500 T-33A/TV-2 type jet trainers built by Lockheed since 1948 adds up to millions of dollars.

Hailed as the world's safest jet trainer, the Navy's T2V-1 SeaStar was built in only 135 working days from start of structural work to roll-out—another Lockheed production record! And because Lockheed has the T2V-1 production line in being, all branches of the U.S. armed services are assured of being able to get the latest and the best jet trainers in the shortest time—modified to suit the special requirements of each.

U.S. Navy T2V-1 SeaStar Jet Trainer

First U.S. plane ordered into production utilizing Boundary Layer Control **1**, *which permits shorter take-offs and safer landings at slower speeds. Aerodynamically actuated slats on wing's leading edge* **2** *contribute superior anti-stall characteristics. Elevated aft cockpit* **3** *gives the instructor excellent straight forward visibility during approaches, landings and take-offs. Oversized vertical stabilizer, and rudder areas* **4**, *and prominent dorsal fin* **5** *provide maximum controllability in all speed ranges. Extremely rugged landing gear, retracted in flight, will withstand terrific punishment incurred in early-training landings on airfields or carrier decks.*

LOCKHEED

AIRCRAFT CORPORATION, BURBANK, CALIF.

LOOK TO LOCKHEED FOR JET LEADERSHIP, TOO

Louis G. Dunn, FIAS, has been elected a Vice-President of The Ramo-Wooldridge Corp. Formerly with Caltech's Jet Propulsion Laboratory, he joined the company in 1954 to direct missile research.

by the Army in the Arctic. Mr. Bird is President and Treasurer of Birdair Structures, Inc., Buffalo.

Louis M. Campani (M) has been promoted to Chief Administrative Engineer of The Liquidometer Corporation.

Andre M. Cels (M) has joined Aérobel (Compagnie Générale Belge d'Aéronautique), Brussels, Belgium, as Director. He was formerly Chief Engineer of the Société Anonyme Belge de Constructions Aéronautiques.

F. A. Cleveland (AF) has been appointed Preliminary Design Engineer of Lockheed Aircraft Corporation's Georgia Division, and will move to Marietta shortly. With Lockheed in Burbank, Calif., since 1946, Mr. Cleveland is a former Chairman of the Los Angeles Section of IAS.

A. P. Fontaine (AF) has been promoted to Vice-President for Engineering, Bendix Aviation Corporation. At the same time, he became a member of the Administration Committee. He was previously Engineering Director.

Rear Adm. Frederick R. Furth, USN (Ret.) (HM), former Chief of Naval Research, has joined International Telephone and Telegraph Corporation as assistant to Harvard L. Hull, AFIAS, President of Farnsworth Electronics Company, an I.T. & T. Division in Fort Wayne, Ind.

Chester R. Gates (M), formerly with Headquarters, USAF, Washington, D.C., has joined Northrop Aircraft, Inc., Hawthorne, Calif. He is in the Office for Development Planning.

Second Lt. Richard L. Geer, USAF (TM), formerly an engineer in the Wind Tunnel Operations Section of Boeing Airplane Company, is now working in the Escape Section of the Biophysics Branch of the Aeronautical Laboratory, Directorate of Research, Wright Air Development Center, Wright-Patterson AFB, Ohio.

B. Allison Gillies (AF) of Jones & Gillies, Inc., has been elected Vice-Chairman of the Board of Directors of Pacific Airmotive Corporation.

Frederick D. Herbert, Jr., (M) has been elected Financial Vice-President of Kearfott Company, Inc. He was formerly Executive Vice-President for Operations.

Peter G. Masefield (HF) has been named Managing Director of Bristol Aircraft Limited, a subsidiary of The Bristol Aeroplane Company Limited, of Bristol, England. He was formerly Chief Executive of British European Airways Corporation.

William L. Mustard (AM), formerly District Manager in Dayton, Ohio, has been appointed Field Service Manager of Link Aviation, Inc.

John W. Myers (M) has been elected Chairman of the Board of Directors of Pacific Airmotive Corporation. He was formerly Senior Vice-President of Northrop Aircraft, Inc.

Second Lt. Philip F. Oestricher, USMC (TM), of Lockhart, Fla., has been transferred from Pensacola Naval Air Station to Chase Field, Beeville, Tex. He is a Student Naval Aviator.

Arthur R. Weckel, MIAS, Vice-President of Sperry Gyroscope Co., has been named Manager of the Special Missile Systems Division. He is in charge of the Sparrow I program for the Navy.

Arthur P. Paine (TM), formerly Chief Engineer, has been named Manager of the Aircraft Division and Assistant Secretary of Bristol Engineering Corporation.

Bruce H. Pauly (M) has been named Associate Director of Research and Development of The Weatherhead Company. A former Lieutenant Colonel in the Air Force, he was until recently Aircraft Sales Manager of Pesco Products Division, Borg-Warner Corporation.

Andre W. Reichel (M) has been appointed Director of Sales and Service of Kearfott Company, Inc. He was formerly General Sales Manager.

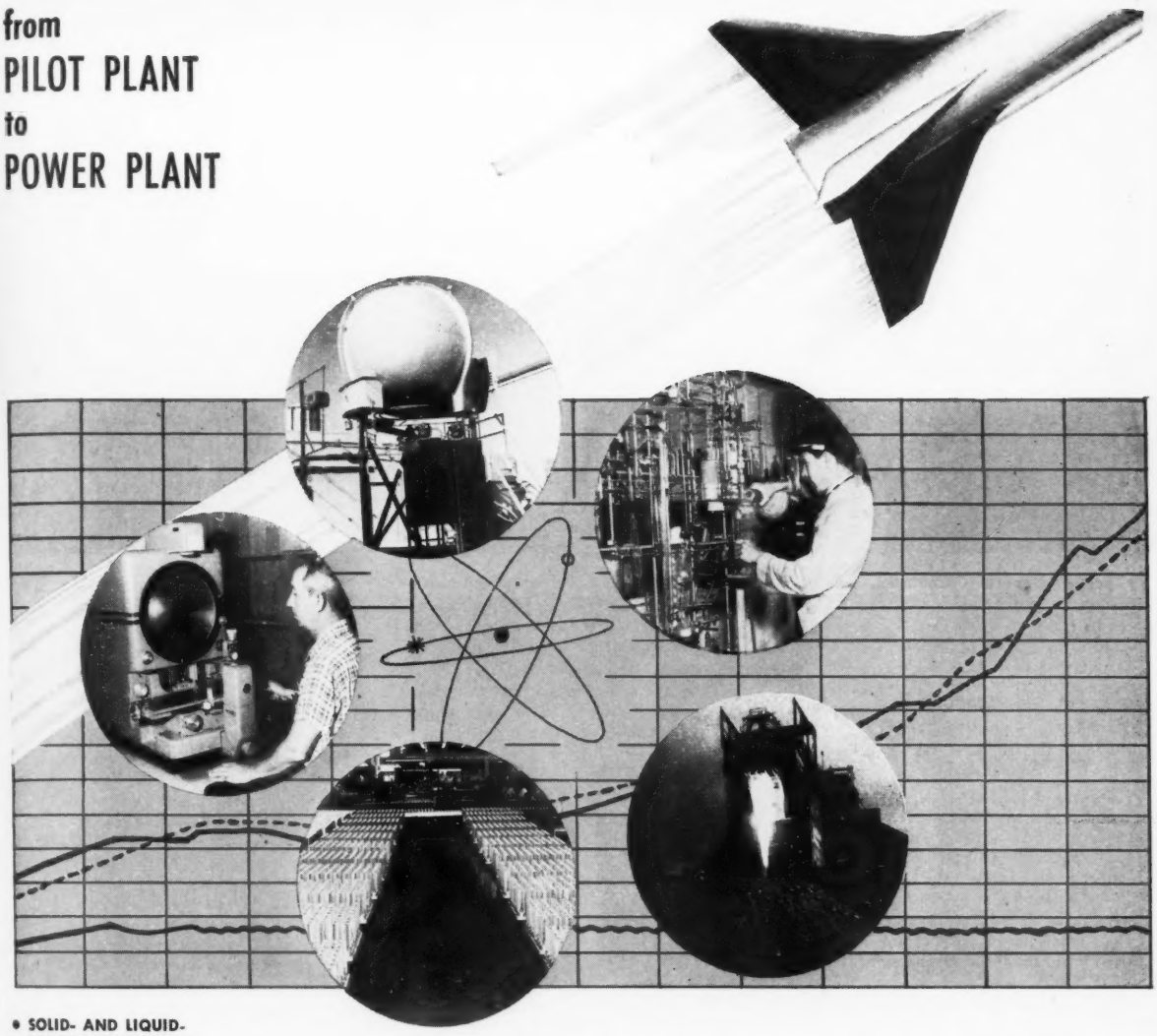
Wladimir A. Reichel (AF), Senior Vice-President for Engineering, General Precision Equipment Corporation, has been elected Vice-Chairman of the Executive

Richard B. Hubbard, MIAS, has been named President of the Erco Division of ACF Industries, Riverdale, Md. He was Vice-President and Chief Engineer of Specialties, Inc.

Donald W. Smith, MIAS, has been elected President of Kearfott Company, Inc., a subsidiary of General Precision Equipment Corp. He was Vice-President and Director of Engineering and Sales.

Norman L. Winter, MIAS, has been promoted to General Sales Manager at Sperry Gyroscope Co., succeeding A. R. Weckel. Mr. Winter was Director of Federal Contracts.

from PILOT PLANT to POWER PLANT



- SOLID- AND LIQUID-PROPELLANT ROCKET POWERPLANTS FOR MISSILE AND AIRCRAFT APPLICATIONS
- AEROBRAKE THRUST REVERSER (SNECMA)
- AUXILIARY POWER UNITS AND GAS GENERATORS
- ELECTRONICS AND GUIDANCE
- ORDNANCE ROCKETS
- EXPLOSIVE ORDNANCE AND WARHEADS
- UNDERWATER PROPULSION DEVICES
- ARCHITECT-ENGINEER SERVICES FOR TEST FACILITIES

QUALITY CONTROL FOR ROCKET ENGINE RELIABILITY

Today, as never before, rocket power is a dominant military requirement. Aerojet-General propulsion devices are used from Pole to Equator. They must operate with the flick of a switch at any altitude, any attitude, over extreme temperature ranges.

But the price of optimum reliability is maximum vigilance. At Aerojet, this means the uncompromising control of every characteristic of every engine, every component in research, development and production.

There are no short cuts to certainty. Aerojet uses all the techniques of modern quality programs — new-design control, acceptance sampling plans, statistical analysis, quality auditing. In actual test-firings of complete rocket systems, Aerojet has spent over six million man-hours since 1942.

The results are unique in the rocket propulsion field: *Aerojet products in field use have an overall measured reliability of 99.6%.*

AEROJET-GENERAL NEEDS: Chemical Engineers • Chemists • Electronic Engineers • Mechanical Engineers • Physicists and Aeronautical Engineers

Aerojet-General CORPORATION

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THE GENERAL TIRE

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MORE POWER FOR AIR POWER

Committee of Kearfott Company, Inc., a subsidiary.

Richard J. Rossbach (M) has joined the Aircraft Gas Turbine Division of General Electric Company, Cincinnati, as a Turbine Design Engineer. He was formerly Secretary of the Subcommittee on Compressors and Turbines, National Advisory Committee for Aeronautics, Washington, D.C.

Alvin C. Smith (M) of Cornell Aeronautical Laboratory, Inc., has been named Manager of Industrial Development and Sales of the newly formed Birdair Structures, Inc., Buffalo.

John W. Thorp (M), formerly of Fletcher Aviation Corporation, has been engaged as a Design Consultant by Air Logistics Corporation. He also heads Thorp Aircraft Corporation.

Maurice A. Walter (M) has joined the Western Division of Servomechanisms, Inc., Los Angeles, as a Project Engineer. He was formerly a Senior Scientist in the Missile Systems Division of Lockheed Aircraft Corporation.

Gerald B. Wright (M), formerly Assistant Manager of the Air Force Sales Department, has been named Manager of the Hustler Systems Department of Sperry Gyroscope Company Division of Sperry Rand Corporation.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation** has been chosen to build the second-stage rocket engine that will carry the first earth satellite through most of its 300-mile assault on outer space. Housed in a Martin air frame and launched from a large booster rocket, the Aerojet power plant will push through the ionosphere a vehicle resembling the Aerobee, carrying the small third-stage rocket and the satellite.

• **Aluminum Company of America . . .** A new hydraulic forging press is being assembled at Alcoa's Vernon, Calif., works as a companion to the 1,500-ton press already in operation there. With three power cylinders, it is expected to be the most versatile forging press of its size in the United States. Operation at 2,700, 5,400, and 8,000 tons capacity will be possible. Alcoa engineers claim they have devised an earthquake-proof method of installation.

• **Arma Division, American Bosch Arma Corporation . . .** John J. Giba, formerly Assistant Chief Engineer, has been named Vice-President in charge of the Contracts Division. Lionel R. Fiedler, formerly Vice-President for Sales, Arma Division, has been promoted to Vice-President of the Corporation.

• **Avien, Inc.,** announces a new portable field and shop tester that provides all necessary instrumentation for checking calibration accuracy and electrical insulation qualities of fuel gage tank units. Designated Model No. 1617-040, the tester corresponds in design and performance to military type MD-2, and may be used for all capacitance type tank units regardless of manufacturer or aircraft application.

• **Avro Aircraft Limited . . .** A special issue of *Jet Age* has been published by A. V. Roe Canada Limited to mark its tenth anniversary. Scott Young, a Canadian magazine writer, prepared the historical account, which is profusely illustrated.

• **Bendix Aviation Corporation . . .** The Pacific Division is working on American versions of the Decca navigation system for possible military and commercial applications. Bendix is licensed to manufacture the Decca system, which has been accepted for air traffic control and navigation by the British Ministry of Transport and Civil Aviation.

• **Boeing Airplane Company** has announced details of its Intercontinental 707 jet transport, which is designed to carry 124 passengers in first-class service or 146 passengers in tourist service. With a full pay load range of 5,000 miles, it will make possible nonstop schedules such as New York to Rome in $7^1/_2$ hours, Los Angeles to Copenhagen in $10^1/_2$ hours, and Tokyo to San Francisco in $9^1/_2$ hours. The giant plane will cruise between 550 and 600 m.p.h. and will be equipped with sound suppressors and thrust reversers for the four jet engines. Gross weight will exceed 280,000 lbs. First deliveries of the Intercontinental are scheduled for 1959.

• **The Cleveland Pneumatic Tool Company** has opened a sales and service branch at 2509 West Berry Street, Fort Worth, Tex.

• **Convair, A Division of General Dynamics Corporation . . .** The Air Force and Convair's Fort Worth Division have announced an experimental project leading toward the development of an atomic-powered aircraft. In recent months, the announcement said, a huge B-36 carrying an atomic reactor has made "numerous successful flights during which the reactor was operated." Among other things, the reactor is used to investigate problems of shielding against radiation, to study effects of radiation on aircraft, materials, and systems, and to develop air-borne nuclear instrumentation. The reactor is never operated during take-offs and landings. . . . Sixty-seven Metropolitan 440 transports have been ordered by various air lines, Convair reports. The Metropolitan is available in 44- and 52-passenger versions.

• **Douglas Aircraft Company, Inc. . . .** A new version of the Skyraider, the AD-7, will be manufactured by Douglas and delivered to the Navy beginning in August. This will be the 50th version of the AD series since the prototype took to the air in March, 1945. Approximately 3,000 of the carrier-based attack bombers have been built, some capable of carrying 10,000 lbs. of bombs. . . . Douglas's new luxury air liner, the DC-7C, is undergoing flight tests at Santa Monica. The plane cruises at 350 m.p.h., has a range of 5,000 miles, and carries up to 85 passengers. . . . Douglas reports orders during 1955 for 98 DC-8 jet transports and 230 propeller-driven DC-6 and DC-7 air liners.

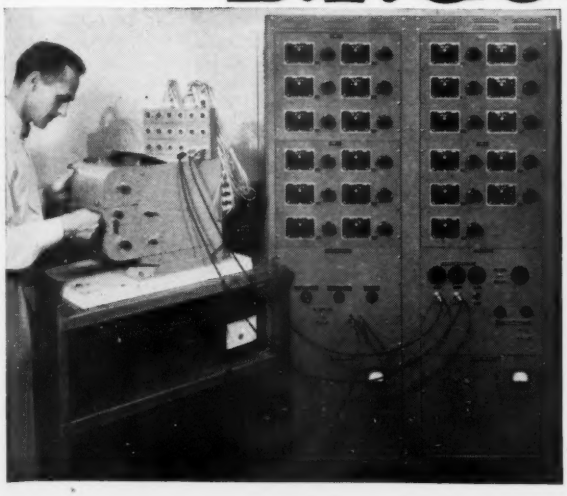
• **Federal Telecommunication Laboratories . . .** Andre G. Clavier, Dudley M. Day, and Brig. Gen. Peter C. Sandretto, USAF Reserve, have been elected Vice-Presidents of this research division of International Telephone and Telegraph Corporation.

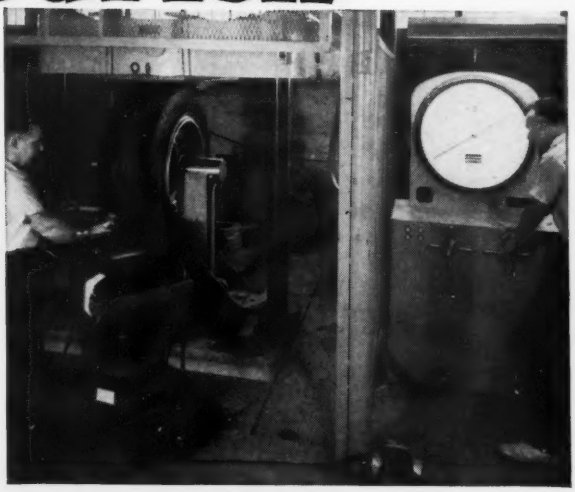
• **General Electric Company . . .** Philadelphia has been selected as headquarters for the Special Defense Projects Department. About 1,000 persons will be employed in a six-story building at 32nd and Chestnut Streets when the move from Schenectady is made this summer. Primarily an applied research and development organization, the department will handle engineering and production of large, highly complex missile systems. It will act as a focal point for the company's engineering and manufacturing resources for missile systems projects requiring the close, coordinated efforts of many G-E organizations. . . . General Electric FPS-8 radar has been installed in the CAA's new Air Route Traffic Control Center at New York International Airport. Originally developed for the Air Force as a long-range search radar, the FPS-8 increases the range for controlling aircraft from the Center to over 100 miles in all weather conditions. . . . A bulletin summarizing the results of an experiment in determining convective heat transfer on a supersonic air frame through use of the V-2 rocket in flight is available from G-E's Special Defense Projects Department, Schenectady, N.Y. Bulletin No. 55SD3 describes procedures and equipment used in the experiment, and is illustrated with graphs presenting data on skin temperatures, pressures measured on the V-2 nose cone, and the altitude and velocity attained during the missile's flight.

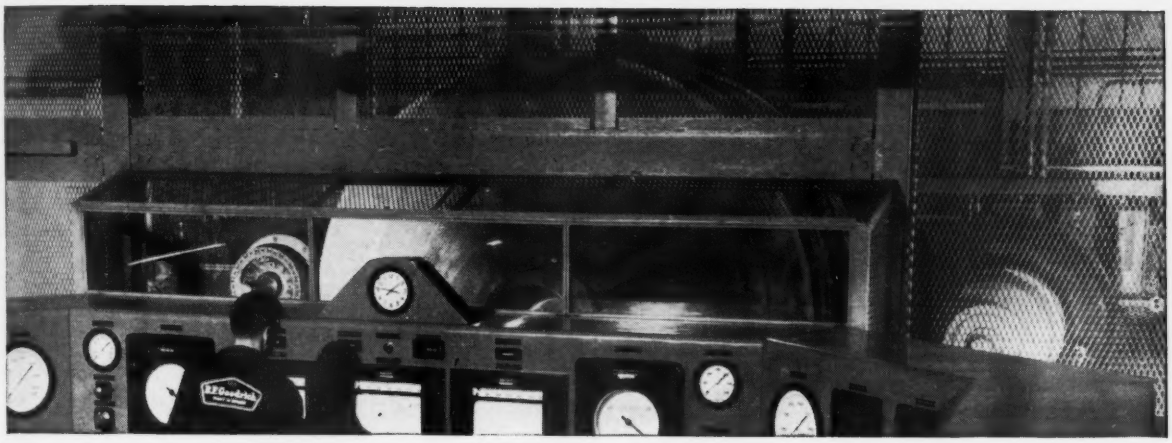
• **General Precision Equipment Corporation** and Royal McBee Corporation have formed a jointly owned subsidiary company with equal interests, named Royal Precision Corporation. Utilizing facilities of both parent companies, the new company will develop, produce, and market electronic data-processing and computation machines and accessory input and output mechanisms, storage devices, and code-conversion equipment for complete data-processing centers for office, scientific, and laboratory use.

• **Jack & Heintz, Inc. . . .** The Engineering Department has been reorganized to handle a heavy influx of development contracts. One division consists of the engineering sections developing alternating-current electric systems. The other is responsible for developing direct-current generators, actuators, engine starters, inverters, and aircraft and commercial motors. A separate Research and Development Group has

RESEARCH KEEPS **B.F.Goodrich** FIRST IN RUBBER







How to land a bomber in a phone booth

BEFORE B. F. Goodrich engineers devised and built the computer in the upper left hand picture, testing a new brake design was a time-consuming process. Laboratory tests of the finished product—sometimes even actual flight tests—had to be made before basic design specifications could be confirmed or modified. But now BFG design engineers have a short-cut. An electronic analog, almost small enough to fit in a telephone booth, simulates a landing and gives preliminary data—in minutes! BFG engineers correct and refine brake design data in the earliest stages, avoid "blind alley" tests that could waste weeks or months.

How do you benefit? We give you faster delivery by speeding up qualification of our brakes. We give you better braking assemblies because we can quickly confirm new engineering and design ideas. And you further benefit by actual dynamometer tests which verify the analog's electronic fortune telling.

At top right you see a BFG forged magnesium wheel passing a terrific static overload test. Strains applied by the 500,000 lb. loading machines are being measured by resistance strain gages and recorded on the oscillograph.

Even more dynamic is the "refused take-off" test on the 250 mph dynamometer. A bomber's *single* wheel and dual brake combination must absorb more than 30,000,000 ft.-lbs. of kinetic energy—as much force as is generated by stopping approximately 65 automobiles going 60 mph—but the BFG brakes bring the plane to a standstill in the specified landing time which assures a safe stopping distance. The wheel is undamaged.

The application of BFG knowledge and experience in research, testing, and quality control, assure you of getting the finest wheels and brakes. *The B. F. Goodrich Company, Tire and Equipment Div., Aeronautical Sales, Akron, Ohio.*

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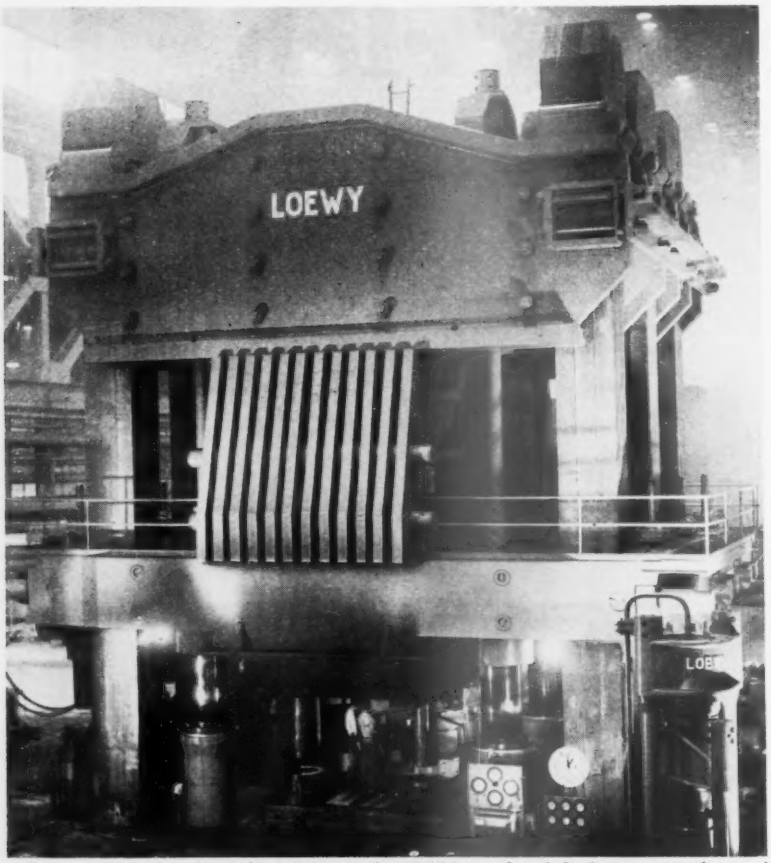

This view shows less than half of "Major," the 50,000-ton closed-die forging press designed and built by Loewy-Hydropress for the USAF Heavy Press Program. The other half extends 60 ft. beneath the floor. Now operating at the Wyman-Gordon plant in North Grafton, Mass., Major can exert a pressure of 106,000,000 lbs. Of its total weight of 10,750 tons, 7,500 tons move. Used for making large aircraft forgings, this press is claimed to be the largest ever built.

been formed to assist both divisions with analyses of certain advanced theoretical aspects of new designs. Additional test facilities are planned. . . . The New York Office of Jack & Heintz has been moved to Room 220 at 390 Plandome Road, Manhasset, Long Island, N.Y.

• **Walter Kidde & Company, Inc.,** announces a new fire detection device for aircraft. It is claimed to be the first one capable of giving an immediate nacelle overheat signal reporting potential danger, followed by a fire alarm if that condition develops. The fire alarm overrides the overheat signal. The device operates on both the fixed-temperature and rate-of-temperature-rise principles. The control unit employs transistors instead of vacuum tubes. It is hermetically sealed and requires no shock or vibration isolation. The new system detects fire in less than 5 sec., requires no resetting after the fire has been extinguished, and weighs less than 3 lbs.

• **The Liquidometer Corporation** has issued a new booklet, Bulletin No. 546, describing true-weight gaging systems, compensated and uncompensated capacitor-type fuel gages, repeater indicators, fuel-gage totalizing systems, selective indicators, and thermistor applications for fuel-level warning and control.

• **Lockheed Aircraft Corporation. . . .** A Special Projects Engineering Division has been set up within the Engineering Branch of the Georgia Division "to meet the fast-growing demand for rapid development of prototype aircraft designs and special systems." Starting with 50 engineers and designers, the new division will add another 100 mechanical, structural, and systems specialists within the next 12 months, the company said. Frank B. Johnson, MIAS, heads the new unit at Marietta. . . . The program of the Lockheed Leadership Fund will be expanded to include graduate fellowships in Theoretical Physics at Princeton University, Aerodynamics at Massachusetts Institute of Technology, and Structures at California Institute of Technology. The 1-year fellowships, valued at $2,500 each, will be in addition to 58 scholarships presently sponsored by Lockheed at various colleges. . . . The C-130 prop-jet Hercules is undergoing cold weather tests at Eglin AFB, Fla .

• **Manning, Maxwell & Moore, Inc. . . .** J. Robert Kelley has been elected President. Formerly Executive Vice-President, he joined the company in 1931.

• **Pan American World Airways, Inc. . . .** Late in 1959, Pan American passengers will ride in the world's largest jet transport, the company claims. This will be the Boeing Intercontinental, a larger version of the 707, capable of carrying 146 tourist passengers or 124 first-class passengers. The new air liner will have a range of 5,000 miles with full pay load, assuring nonstop transatlantic schedules under all weather conditions. P.A.A. placed the first air-line order for twelve of the 575-m.p.h. Intercontinentals. . . . Having accumulated 20,000 hours flying experience with air-borne radar, Pan American plans to spend $1,000,000 for radar for its fleet of 45 jet transports now on order. Altogether, $3,000,000 will be spent to equip 129 long-range aircraft with radar. . . . During 1955, Pan American set new records for air cargo on its trans-Atlantic and Latin-American runs.

• **J. B. Rea Company, Inc.,** announces a new series of subminiature rate gyroscopes 1 in. in diameter, $2^1/_8$ in. long, and weighing 4 oz.

• **Ryan Aeronautical Company** will manufacture $20,000,000 worth of jet power packages for the Douglas DC-8 jet transports ordered by commercial air lines. The Ryan jet pack is a quickly demountable, complete power unit composed of the jet engine and its supporting structure and electrical and mechanical accessory equipment, including fuel and oil systems and hydraulic, pneumatic, electrical, and anti-icing systems. The J57 engine will be furnished by Pratt & Whitney Aircraft Division of United Aircraft Corporation. . . . Huge external fuel tanks, claimed to be the world's largest, are being built by Ryan for hundreds of Boeing B-47 jet bombers. No longitudinal members, baffles, nor external rivets are employed in constructing the tank. More than 30,000 spotwelds join the tank skins into a smooth, skin-stressed envelope of high strength.

• **Shell Oil Company** has designed a new type of truck for refueling turboprop transports such as the Viscount. The hose pumps 200 gal. per min. in underwing refueling. The truck carries 4,600 gal. of fuel and 420 gal. of a power-boost fluid, water-methanol.

• **Solar Aircraft Company . . .** An Air-Frame Parts Plant with 45,000 sq.ft. has been established in San Diego, near Solar's main plant. The building was formerly used as a warehouse.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation . . .** The Seattle office, stock rooms, and repair shop have been moved to 300 West Harrison Street.

• **United Aircraft Corporation . . .** Hamilton Standard Division has purchased the Aero-Pneumatics Division of Pacific Airmotive Corporation, Burbank, Calif. The acquisition gives Hamilton Standard manufacturing rights strengthening its position in the field of air conditioning systems for aircraft.

• **Western Gear Corporation . . .** A new Engineering Building is under construction near the Lynwood, Calif., plant. Designed to accommodate 200 engineers, it will have 20,000 sq.ft. of floor space and will cost $250,000. The building will be air-conditioned and windowless on three sides.

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IAS SECTIONS

Meet Your Section Chairman

Major Vincent J. Bracha, USAF

Rocky Mountain Section

Major Vincent J. Bracha was born in Bristol, Conn. After graduating from high school in 1938, he entered the textile business in New Britain, Conn., and continued in this work until he joined the Air Force in 1942.

He began flying in 1939, soloing in a Taylorcraft, and has been flying ever since.

Endeavoring to complete his education, he entered the evening school of Hillyer College in 1940, but this course was short-lived because of the onset of World War II.

On July 1, 1942, he joined the Army Air Corps as a glider pilot (sergeant) and continued flying light planes and gliders until June, 1943, when he left the Air Corps Glider Program to begin pilot training. In December, 1943, he graduated from flying school and was rated a pilot. He received his commission as a second lieutenant.

In April, 1944, Major Bracha went overseas and flew 92 combat missions in the Mediterranean theater, piloting P-47 Thunderbolts. He was shot down over enemy territory in September, 1944, and, after evading capture for more than 2 months, found his way to friendly forces and returned to the United States.

During the next 5 years, Major Bracha served at various air bases in the United States and Germany as an instructor-pilot, operations officer, and maintenance engineering officer.

Returning from his second overseas tour in 1949, he resumed his education during after-duty hours and was able to complete the first 2 years of college at various institutions where he had been stationed—Rhode Island State, New Bedford Polytechnical Institute, University of Illinois, and University of New Mexico.

He thus qualified for the Air Force Institute of Technology at Wright-Patterson AFB and enrolled there in the summer of 1951. He received his Bachelor of Science degree in Aeronautical Engineering in 1953.

Major Bracha then was assigned to Headquarters of the Air Defense Command at Colorado Springs, Colo. His present assignment is as Chief, Lockheed Aircraft Branch, in Maintenance Engineering.

Boston Section

The December 14 meeting was held at Massachusetts Institute of Technology with 85 members and friends in attendance. Chairman Robert L. Halfman introduced H. Guyford Stever, Chief Scientist, USAF, whose topic was "Some Aeronautical Challenges."

Dr. Stever discussed the technical challenges which face the aeronautical engineer. With the advent of the century series of fighter aircraft, new control problems such as loss of directional stability and the effects of aerodynamic heating on structure and crew have presented such challenges. Bombers which travel at supersonic speeds are similarly affected.

Another order of difficulty exists for guided missiles because of their dependence on fully automatic operation. Today, on the threshold of space flight, the aeronautical engineer is confident of his ability to achieve a velocity of 25,000 ft. per sec. to the extent that Project Vanguard has been officially scheduled for the International Geophysical Year. The intercontinental ballistic missile, with its problems of aiming accuracy and re-entry into the atmosphere, presents perhaps an even greater challenge. The adoption, at least for long-range bombers, of nuclear power with the attendant shielding difficulties is still another challenge.

Dr. Stever then turned to the question of our ability to produce the advances needed to meet these challenges. With the large number of problems wanting solution and a limited available number of engineers and scientists to work on them, he called upon those having technical capability to be sure that their work is of importance.

He also pointed to the responsibility which engineers and scientists hold with regard to public pronouncements, predictions for the future, and estimates of times required to complete tasks ranging in character from pure research to pure production. Overoptimism in such estimates, although sometimes due to sales department pressures, is also caused by engineers themselves in trying to set goals which force them to extend themselves to the utmost. Such great efforts induce a state of mind wherein each project is regarded by its leaders and workers as being of highest priority. In the overall effect on the military strength of the nation, all efforts cannot be of the same degree of importance, and the technical community must bear the responsibility for the accuracy of estimates of this sort.

WALTER MCKAY, *Secretary*

Dayton Section

At the meeting on December 8, 75 members and guests heard Capt. Willard M. Hangar, USN, Executive Assistant to the Director of the Research and Development Group, speak on the subject of Naval carrier aircraft operations and special equipment.

Captain Hangar's talk was bolstered with slides and movies of recent carrier aircraft trials, illustrating the latest materiel. The audience, which was predominantly associated with the Air Force, was impressed by the carrier operations shown. Captain Hangar described the design and other problems associated with carrier catapults, starting with the hydraulic type that was popular on the Essex-class carrier during World War II and covering the steam catapults that were developed after the war. Brief mention was also made of catapults employing the gases evolved by solid-propellant charges. A fairly complete description of the present steam catapult, with its advantages, was amplified in the slides and movies.

Arresting gear and barriers were also described, starting with World War II types. The evolution of the more complex types, which are capable of arresting and stopping high-landing-speed jet aircraft, was clearly described and illustrated. The most interesting development, the angled deck, which permits landing of jet aircraft with 90 per cent throttle settings, thus allowing for take-offs without endangering parked aircraft and crews, was described, and the movies showed interesting demonstrations of its use. Many questions followed Captain Hangar's talk.

▶ On September 20, 85 members and guests of the Dayton Section met at Levitt's for dinner and a talk by Hugh F. Jacox of Capital Airlines, Inc., on experiences with the new Vickers Viscount transport.

Boeing engineers find rewarding jobs in Wichita, Seattle

This model of a supersonic airplane design was dropped at extreme altitude from a B-47 Stratojet. Telemetered data revealed the characteristics of its supersonic flight to destruction at the earth's surface. This is just one example of Boeing-Wichita's continuing development of advanced aircraft and associated systems.

At Wichita research and development programs are expanding rapidly. Laboratory space has been quadrupled and many other new engineering facilities have been added to keep pace with increasing emphasis on technical development. At both of the company's plants, Seattle and Wichita, the increased scope and magnitude of this development effort is creating additional and excellent career opportunities for aeronautical engineers.

This means there is a real challenge for you in one of Boeing's design, research or production engineering programs. Among the interesting assignments for aeronautical engineers at Boeing are all of the major engineering and scientific fields, including aerodynamics, propulsion and thermodynamic analysis, structural design and stress analysis. Working in tight-knit teams provides plenty of room for self-expression and recognition.

Boeing engineers are working now on future airplanes and missiles that will maintain the standard of technical superiority established by the B-47 medium bomber, the B-52 intercontinental bomber, the BOMARC IM-99 pilotless interceptor, the 707 jet transport and the KC-135 jet tanker-transport.

Recognition of professional growth is coupled with career stability at Boeing — twice as many engineers are now employed by the company as at the peak of World War II. They enjoy a most liberal retirement plan. How would *you* like a satisfying, creative job with the pick of the engineering profession? There may be one waiting for you in the progressive communities of Wichita or Seattle.

R. J. B. HOFFMAN, Administrative Engineer
Boeing Airplane Co., Dept. A-49, Wichita, Kansas

JOHN C. SANDERS, Staff Engineer — Personnel
Boeing Airplane Co., Dept. A-49, Seattle 14, Wash.

If you want further information on the advantages of a career with Boeing, please send coupon to either of the above addresses.

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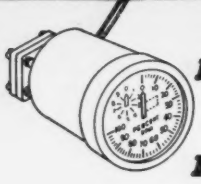
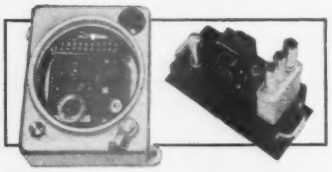


Reads Jet Engine Speed to Guaranteed Accuracy of 10 RPM in 10,000 RPM (±0.1%)

The new B&H TACKAL incorporates a refinement of the frequency meter principle. It operates in the low (0 to 1000 cps) range, reading the frequency of the tachometer generator on a scale calibrated in percent RPM corresponding to the engine's RPM. In addition the TAKCAL checks the tach system. The TAKCAL circuit and tachometer are parallel so that readings can be made simultaneously to determine the accuracy (or inaccuracy) of the aircraft's tach system. The TAKCAL operates during the engine run to properly set up engine controls for maximum economy and safety.

Originally developed as a component part of the J-Model JETCAL ANALYZER, the TAKCAL is now available as a separate unit for use with all earlier models of the JETCAL TESTER.

The TAKCAL operates accurately in all ambient temperatures from −40°F. to 140°F. Low in cost for an instrument of such extreme accuracy, it is adaptable to application in many other fields.



Explosion-proof TAKCAL for special applications. Measures 200 to 7500 RPM, direct reading, with ±0.1% accuracy.

For full information write or wire . . .

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Mr. Jacox presented a movie which showed scenes taken during the fabrication of the Rolls-Royce turboprops used in the Viscount and some interesting demonstrations of the fine methods of construction and the excellent results obtained, particularly in regard to smoothness of operation. Following the movie, Mr. Jacox listed statistics as to the schedules resulting from Viscount use and told some surprising figures on Viscount operation. He said the turboprop engines were more rugged than had been anticipated and maintenance costs were less than anticipated.

T. J. KEATING, *Secretary*

Hagerstown Section

The December 13 meeting was called to order by Allen Clopper at the Hotel Alexander. James A. Neilson, Jr., Chairman of the Membership Committee, presented a progress report.

W. H. Arata, Program Chairman, introduced the speaker, Paul E. Garber, Curator of the National Air Museum in the Smithsonian Institution, Washington, D.C. Mr. Garber spoke on the history of the air mail and showed a film of the Wright brothers' demonstration flight for the Army at Fort Myers, Va., in 1909.

A color film on the Bell X-1B research airplane was exhibited. Seventy-six attended the meeting.

C. L. CHUMLEY
Secretary-Treasurer

Rocky Mountain Section

Major Gen. Marshall S. Roth, USAF Deputy Chief of Staff, Material Headquarters, Air Defense Command, addressed the second meeting on December 3 at the Officers Club, Headquarters ADC, in Colorado Springs, Colo. General Roth's subject was "Development of an Aircraft Weapons System" in which he discussed the complicated planning necessary to effect the successful development of a weapon for a specific task. He likened such a development to the project faced by a housewife in preparing and serving a meal to the boss. This involves consideration of the same elements of planning, programing, material, facilities, personnel, and delivery as in the weapons system synthesis, with one important contrast in the end objective. Where the housewife wants the boss to enjoy the meal (presumably), the weapons system designer tries to determine what the enemy would dislike the most in the given situation.

Following General Roth's address, Richard Frost presented the names of candidates selected by the nominating committee, and the entire list was

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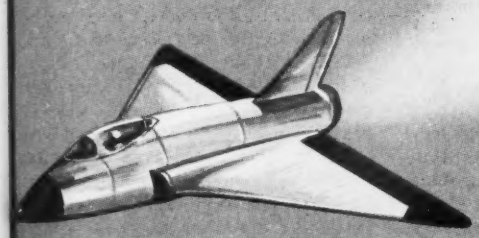

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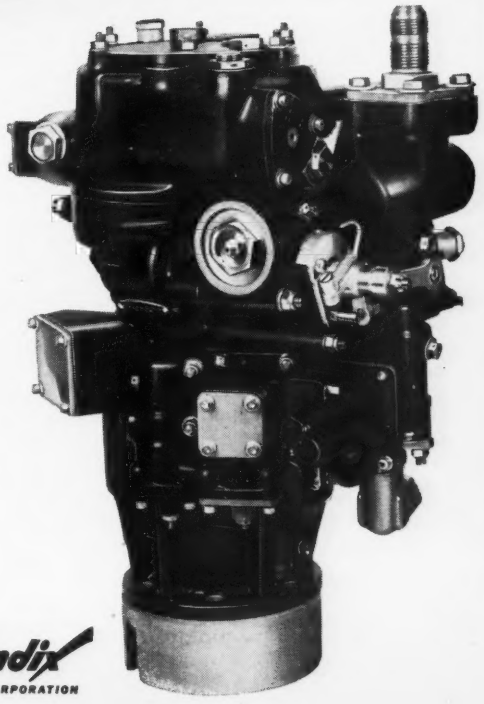

This advanced type fuel metering unit was developed by Bendix to include special features for the 10,000-pound thrust class Pratt & Whitney J-57 turbojet—the engine which puts the power behind the super performance of the F4D Skyray.

As early as 1945, Bendix brought out a jet engine control which automatically metered fuel during engine acceleration and deceleration so as to avoid over-temperature, compressor stall and "flame out". Since then, these features have become a "must" on all jet engine controls, allowing the pilot to slam the throttle wide open without danger of ruining the engine, or slam it shut without risk of "flame out".

Bendix fuel metering is used today on nearly all American airliners, and on a great majority of military aircraft. This includes injection type carburetors and direct fuel injection, as well as fuel metering and complete engine control systems for jets.

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Colonel William B. Bunker, USA, talks with Harold H. Ostroff, Program Chairman, and Hermon H. Cole, Section Chairman, after addressing a joint meeting of the IAS St. Louis Section and the American Helicopter Society on "One-Man Flying Machines." Colonel Bunker is President of the AHS.

approved by unanimous vote. The following officers were elected:

Chairman, Major Vincent J. Bracha, ADC; Vice-Chairman, Alison M. Arnold, Stanley Aviation Corporation; Secretary, Arthur W. Gilmore, University of Colorado; and Treasurer, Major William R. Fuchs, Air Force Academy.

The Advisory Committee consists of Major Gen. Marshall S. Roth, ADC; Lt. Col. Gerhardt C. Clementson, Air Force Academy; Lt. Col. William A. Larson, ADC; Professor Harold W. Sibert, University of Colorado; Alan F. Bonnalie, United Air Lines, Inc.; Richard H. Frost, Stanley Aviation Corporation; W. G. Purdy, The Glenn L. Martin Company; and Richard B. Bosworth, Beech Aircraft Corporation.

Professor K. D. Wood, of the University of Colorado, was chosen Area Representative.

The enthusiasm of our Section members is shown by the fact that many of them drove between 70 and 90 miles through a snowstorm to attend this meeting in Colorado Springs. We are looking forward to a sizeable expansion of the Section as soon as Martin and Ramo-Wooldridge move into the Denver area in force. The next meeting will be held at the Air Force Academy in Denver.

ARTHUR W. GILMORE, *Secretary*

Flying Platforms

St. Louis Section

On December 15 in a joint meeting with the St. Louis Section of the American Helicopter Society, IAS members heard Col. William B. Bunker present a "state of the art" review of one-man lift devices. Colonel Bunker is Commanding Officer of the Army Transportation Supply and Maintenance Command, located in St. Louis, and President of the AHS.

Colonel Bunker pointed out that initially "one-man flying machines" represented a first design that was later destined to grow in size and carrying capacity but that today there are many designs of individual lift devices that represent an end in themselves. He reviewed briefly the design and performance of the Goodyear GA-400, the Hoppicopter, the Hiller XH-32, the Rotor-Craft Pinwheel, the American Helicopter XH-26, the McDonnell XH-20, and the French Djinn.

He described the DeLackner inverted rotor system, which uses a 44-hp. outboard motor to drive a 15-ft. diameter rotor, and contrasted it to the Hiller shrouded-propeller flying platform. The Hiller platform uses two 40-hp. engines to drive contrarotating propellers of $3^1/_2$-ft. diameter. It is not considered to be a helicopter and has no fail-safe characteristics in the event of total power loss. The DeLackner and Hiller designs are known as "stand on" machines.

In discussing the possible future use of individual lift devices by the Army, Colonel Bunker explained that the mission of the foot soldier is to hold a piece of ground or to take a piece of ground from an enemy. Since individual lift devices have been considered primarily for use by the foot soldier, Colonel Bunker analyzed employment of these devices as an aid in infantry maneuvers. He explained that a soldier must be on the ground to fulfill his mission. Mobility to and from the battlefield, if accomplished by individual machine, requires acquisition of and disposal of the machine, subsequent salvaging of the machine, additional specialized training of personnel, and limitation of use to volunteers receiving extra pay under existing military policy. He stated that in his opinion there was no practical individual device today that solved the problem of movement and that a transport vehicle such as a large helicopter, airplane, or truck would be employed in preference to the one-man type of machine.

It was brought out that the work to date on individual lift devices has been the result of pure research or of private financing wherein it was assumed that the attainment of satisfactory performance would assure military acceptance—this without an absolutely clear understanding of military requirements.

Colonel Bunker felt that the development of a single-purpose, two-place machine was a much more desirable field of endeavor, since a full-time operator could transport a field commander as required with no demands of time or skill superimposed on the heavy battlefield duties of the commander. The two-place vehicle in the form of the jeep replaced the military motorcycle for this reason. With improved methods of jamming radio communications, the need for carrying written messages and making oral reports also becomes increasingly important.

FREDERICK H. ROEVER
Recording Secretary

San Diego Section

"Clear Design Thinking Using the Aircraft Growth Factor" was the subject of the paper delivered at the dinner meeting on December 13. William F. Ballhaus, Chief Engineer of Northrop Aircraft, Inc., made an excellent presentation on the use of the growth factor in aircraft design.

It was shown that the aircraft growth factor is a tremendously effective tool in both design and evaluation of design. Dr. Ballhaus indicated how the growth factor can be used to help determine the right combination of the important aerodynamic and structural variables and, finally, can be used to determine the minimum weight aircraft to meet any fixed requirements.

R. L. Bayless, Chief Engineer of Convair-San Diego, served as technical chairman of the meeting and added to the presentation by his own comments.

R. A. FUHRMAN
Corresponding Secretary

San Francisco Section

The dinner meeting on November 17 was preceded by the usual social hour. Then Chairman Ed Quarterman introduced the speaker, Harold Adams, Chief Designer, Douglas Aircraft Company, who gave a talk on the Douglas jet transport—the DC-8. The talk was illustrated with slides and interesting sidelights on the design.

In outlining his requirements for a jet air liner, Mr. Adams specified that the aircraft must, first, attract the passengers and, second, carry them economically. With speed and fare equal, safety, reliability, and comfort were the next most important features to go into the design of a transport airplane.

Mr. Adams then discussed many of the features of the DC-8 in order to show how these points were carried out. Safety features included making an airplane that was easy to fly and that operated by easily maintained, dependable systems. Comfort features of the DC-8 include reduction in noise level through adequate use of sound insulation. A number of slides were shown and discussed comparing the DC-8 with the DC-7. A surprising fact was that operating costs in cents per 200 lb. nautical mile were actually less than for the DC-7 out to beyond its maximum range. This economy of operation also remained in favor of the DC-8 at short ranges down to about 200 miles. A typical New York-to-Los Angeles flight of the DC-8 against a 43-knot headwind would be completed in 5 hours and 19 min. with a block-to-block speed of 404 knots. The take-off distance required would be 6,700 ft., and the landing distance would be 6,100 ft.

Servicing considerations included provisions for removing all baggage and cargo in 5 min., allowing for sufficient clearance for baggage handling equipment to move freely underneath the airplane, and provisions for underwing refueling.

Dependability has been ensured by using further simplified and improved systems that were originally developed on the DC-6 and 7. Structural fatigue has been thoroughly studied on the DC-6 and 7 and this knowledge applied to the DC-8, making it free of fatigue problems.

It was pointed out that one reason for the delay in introducing the DC-8 was the lack of traffic potential. The increasing air traffic rate in billions of seat miles was displayed graphically, showing a rise from about 20 in 1940–1945 to 80 in the past year. In terms of return per dollar invested, the DC-8 was shown to provide a greater return over the DC-7 at all passenger load factors.

Operating characteristics were summed up by stating that the DC-8 was designed to operate over the same airways and airports as our present transports. The J-57 engine being used is one of proved reliability. Typical approach air speeds with 50° of flap were given as 145 knots on downwind, 130 on base leg, and 115–117 over the fence. Twenty per cent more runway would be required by the DC-8 on a hot day, however, over the DC-7.

Take-off noise will be reduced by using a corrugated jet nozzle. Primary fuel control will be mechanical. An a.c. electrical system supplied by dual alternators on each engine is to be used. The hydraulic system is an improved DC-6 -7 system. The landing gear has been designed to free-fall and lock by gravity. The rudder and ailerons are to be power-boosted, while the elevator will be tab-boosted. The ailerons will have a tab for standby operation, however. A flap lift-spoiler is to operate automatically upon landing to kill lift and aid braking. A thrust reverser will be incorporated also to decrease landing roll. Dive brakes for speed control will be similar to the fuselage brakes on the AD series.

In summary, it was pointed out that all improvements in the DC-8 were evolutionary rather than revolutionary and as such should add to safety and reliability.

▶ The San Francisco Section met in Palo Alto on October 20 for the regular dinner meeting. Chairman Ed Quarterman introduced the speaker, Howard M. Mulder, Assistant Western Manager for Allison Division of the General Motors Corporation, who spoke on the T-54 turboprop engine.

Mr. Mulder first described the engine as a 1,700-lb. unit, comprised of a 14-stage compressor and 4-stage turbine, turning at 13,800 r.p.m., and with a 12.5 to 1 reduction to the propeller. It was rated at 5,000 equivalent s.hp. at 600 knots. It was pointed out that the T-56 cruises at 85 per cent normal rated power as compared with 60 per cent NRP for the turbocompound engine. Fuel used is either JP-4 or kerosene.

A decoupler is actuated at any time negative torque is applied to the propeller shaft in order to keep windmilling drag down to 200 hp. by preventing the propeller from driving the engine. A specially designed torquemeter was described which had been developed for this engine. A separate oil supply is provided for the propeller. Inexpensive 1010 steel replaceable burner liners are used which are automatically changed at overhaul. Automatic feathering is accomplished when the propeller loses positive thrust and

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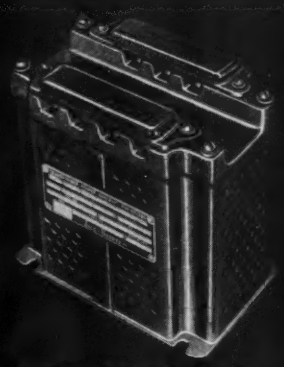

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pushes back, compressing a special washer.

The speaker then described briefly the new 100 million dollar Allison Research Center, dwelling mainly on the Endurance Test Cell and the Component Compressor Laboratory. He told of the tremendous vibrations experienced with the larger turboprops in the test cells. Compressor sections were tested using ram air from other special compressors. The turbines were checked at 120 per cent overspeed to ensure against wheel failure.

Water injection was also described with reference to how it may be used, especially on hot days, to bring back performance to that for a standard day.

▶ The first dinner meeting of the season was held September 22. Chairman Ed Quarterman presided and introduced the speaker, Richard Gompertz, Chief of the Rocket Engine Test Laboratory at Edwards Air Force Base.

Mr. Gompertz described, in an interesting and amusing manner, the history and problems associated with the early tests of the X-1 rocket engine and the growing need for suitable test facilities which finally resulted in the present Edwards Laboratory. A color movie on the rocket test activities was shown, followed by a more complete description of some of the equipment.

It was pointed out that instrumentation consisted primarily of 20-channel telemetering equipment and 80-channel consolidated oscillographs. Instrumentation could be switched from one test to another in about 30 min. Fuel storage tanks were shown located some distance from the test stand. Prior to the actual running of a test, the fuel was transferred in smaller quantities to the test stand. Nitrogen and helium at 3,000 psi were used for pressurization and transfer of the fuel. It was of particular interest to learn that the necessary valves for transfer were all manually operated. Although helium was received by car load lot, liquid oxygen was obtained by the truck load and had to be handled rapidly to reduce the transmission loss. For example, transfer of 5,000 gal. in 25 min. results in a 30 per cent loss. The fire extinguishing system was described. Because of all the problems associated with these operations, only one out of five runs was completely successful.

Special problems associated with the very high temperatures both in and out of the rocket flames were discussed. These temperatures were 5,000°–7,000° in the flame and 4,500° on the concrete surface below the flame. The engines themselves were cooled by first passing the fuel around the engine before it entered the combustion chamber.

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Combustion stability problems were pointed out as among the most severe. While striving for stability, in actual operation it was often a case of accepting the best that it was practical to obtain. It was pointed out that some tests may run into a year in the establishment of steady flow conditions. Recent developments have made possible the throttling of some engines down to 20 per cent of their thrust.

Mr. Gompertz stated that there has been more interest in developing reliability than in increasing the specific impulse.

GEORGE E. COOPER, *Secretary*

Twin Cities Section

The December meeting was called to order by Vice-Chairman Hermann, with 50 members and guests in attendance.

Three aeronautical films from the IAS film library were shown: *NACA Pilotless Aircraft Research, Douglas Skyray Speed Runs,* and *D-588-2-Skyrocket.*

New officers were elected as follows: Chairman, Dr. Rudolf Hermann, University of Minnesota; Vice-Chairman, Tom Chase, Minneapolis-Honeywell Regulator Co.; Secretaries, Herb Johnson, Research Incorporated, and Robert Holdahl, Flui-Dyne, Inc.; and Treasurer, Art Jones, Minneapolis-Honeywell.

Dr. Hermann reviewed the program for the remainder of the season and promised that, as Chairman, he would do his best to maintain the high standards of the Twin Cities Section.

▶ Helmut Heinrich was guest speaker at the November meeting. Dr. Heinrich, a technical adviser to the Parachute Branch of Wright Air Development Center, spoke on "New Concepts of Parachute Design." He was introduced by Dr. Hermann, then Vice-Chairman of the Section and an old friend.

Dr. Heinrich introduced his discussion by observing that parachutes are used for a great variety of purposes because they have such a high efficiency. Among the uses named were saving men, delivery of equipment, recovery of guided missiles, drag brakes, and bomb stabilization. The three types of parachutes most used in the past include the circular flat chute (American), the square flat (Russian), and the triangular flat (German). The instability of these types has given rise to several new designs in use today.

The new parachutes may be classified into two general groupings: the porosity chutes and the shaped chutes. The former consists of the conventional types named earlier which are of low to medium porosity and the ringslot and ribbon chutes which are of high porosity. Rotating parachutes comprise a special group that also falls into this classification. Ribbon chutes are composed of a series of spaced ribbons extending from the base of the chute to its apex. Ringslot chutes consist of a series of spaced circular ribbons. In either case, the high porosity tends to increase the inherent stability and reduce the opening shock. These chutes are widely employed as drag brakes, etc. Rotating parachutes have guide slots which cause rotation, thus expanding the chute further for greater drag.

The shaped chutes may be further subdivided into the formed gore and the guide surface types. The formed gore chutes may be either semispherical or parabolic or may have extended skirts. These, too, are more stable than the basic types. The guide surface chutes utilize a partially closed opening. They are designed to particular configurations based upon wind-tunnel examinations of the flow patterns around them in such a manner that aerodynamic stability of a high order is achieved, even at supersonic velocities.

A number of variations of these basic types of parachutes may be found. They include steerable chutes, parachute clusters, etc. Several variations

were also discussed, along with the particulars of parachutes used for specific purposes.

Dr. Heinrich's presentation was followed by a spirited question-and-answer session which was enhanced by the comments of Major Oakley, an experienced parachutist from Wright Air Development Center. Robert Hoel presided.

H. C. JOHNSON
Recording Secretary

STUDENT BRANCHES

Agricultural & Mechanical College of Texas

The December 6 meeting was held in connection with the annual Open House. Among those present were some 40 freshman students and 15 Student Branch members. Chairman Robert C. Barlow introduced the speaker, Doyle T. Brooks, Chief of Structures at Temco Aircraft Corporation, Dallas.

Mr. Brooks discussed some of the aspects of a structural designer's job in aircraft design. Among the high points in his talk were some of the design and analysis problems encountered and the subsequent solutions to them.

At the close of the meeting, E. E. Brush, Head of the Aeronautical Engineering Department, welcomed the new students and invited them to take part in the Open House program. After the meeting was adjourned, the freshmen were taken on a tour of the Aeronautical Engineering Department's labs and test facilities.

HARLESS R. BENTHUL, *Secretary*

Boston University

A lecture and demonstration on the application of servomechanisms in aircraft highlighted the January 4 meeting.

Herbert T. Wexler, advanced research engineer of Sylvania Electric Company's Missiles Division, delivered a slide-illustrated lecture to student members and guests gathered at the Boston University Faculty Club. In his talk, he included basic concepts, definitions, and illustrations of servomechanisms. Much of his speech was devoted to an explanation of proportional, rate, and integral control, the three types associated with servomechanisms. In addition to this, a number of the capabilities and limitations of present-day servos were discussed.

A demonstration of mechanical development apparatus for solving rotational problems was given by William A. McCutcheon, sales engineer, of Servomechanisms Incorporated, Westbury, N.Y. The main emphasis was directed toward the control of oscillatory motion, a condition which occurs during the damping of a vibrating system.

ANNE EVEREST, *Secretary*

Massachusetts Institute of Technology

On December 5 the M.I.T. Student Branch met to hear Paul E. Sandorff, Associate Professor of Aeronautical Engineering, give a thought-provoking talk on thermocontrol problems of space vehicles. He is currently in charge of a new course on orbital space vehicles which will be given this spring.

In the talk, Professor Sandorff emphasized the problem of dissipating the heat which a space vehicle may encounter. By considering the radiation effects on a stationary sphere between the earth and the sun, as an example, it was pointed out that the sphere could reach very high temperatures, depending on its dimensions and composition. A sphere made of aluminum would transmit the high-energy waves from the sun but would reflect the low-energy heat waves produced from within, causing the sphere to heat up. An increase in the size of the sphere would also aggravate the situation. The actual determination of the temperature and its gradient around the sphere was shown to be a tedious process because of the numerous variables that are involved. Possible solutions speculated that the vehicle would have to be small and thick-shelled or else employ a double shell for insulation if it were to be made of aluminum. In conclusion, Professor Sandorff stated that this was still a new field and that there are many opportunities for those with a pioneering spirit.

The Student Branch received a group picture from the Sikorsky Aircraft Division of United Aircraft Corporation depicting a plant tour which was taken on Armistice Day.

The meeting was presided over by Chairman Herbert W. Gewehr with about 50 members present.

PAUL OKAMOTO, *Secretary*

The Pennsylvania State University

Eighty engineering students attended the December 14 meeting, as well as members of the Society of Automotive Engineers and American Society of Mechanical Engineers.

Chairman James Tedeschi handed the meeting over to the speaker of the evening, W. J. Kaufman, Chief Engineer of the Naval Aircraft Factory. Mr. Kaufman described development work going on at the Naval Aircraft Factory and, in particular, launching and arresting equipment for aircraft carriers. He presented his material in an interesting manner, first indicating the desired results, then mentioning several designs to achieve these results, and finally the problems involved in each design. Films and slides of various launching and arresting techniques were shown.

JOEL PETERSON, *Secretary*

University of Colorado

Two Boeing representatives, James F. Schuelke and Jack R. Green, Sr., from Wichita, Kan., attended the December meeting. They exhibited a film, *Boeing Presents*, which described each type of plane Boeing Airplane Company has produced, including the B-52.

At the annual Slide Rule Follies presented by the Engineering School, each engineering department gave a skit. The IAS actors, coached by David Golobe, won first prize of $25 and a bronze plaque.

HAROLD J. BARTLESON, *Secretary*

University of Illinois

The fourth meeting of the Student Branch was held December 7, with 165 persons attending.

Professor Hilton introduced the speaker for the evening, Madison L. Ramey, Chief Structural Research Engineer of the McDonnell Aircraft Corporation. Mr. Ramey's talk was entitled "The Walking Voodoo," or more specifically, "A Problem in Landing Gear Dynamics Caused by Unstable Skidding Friction Experienced by the McDonnell F-101 Voodoo."

This "walking" of the airplane was first noticed by test pilots. When the airplane is braked, the tires alternately adhere and break loose, causing the landing gear to vibrate, sometimes violently. When this was first discovered, M.A.C. ran ground tests on the F-101 at various speeds and at braking attitudes with the oleo strut normally and fully extended. The films of these tests were shown at the meeting. The Voodoo used in these tests had a spar torn loose in one wing and rivets loose in the other wing, and

the nose skin was buckled from the vibrations encountered. Mr. Ramey stated that in modern aircraft design it is impossible to predict all such happenings as this skidding phenomenon. M.A.C. had not encountered this specific trouble on its previous fighters (all Navy) possibly because of the larger stiffness of the Navy design criteria as compared with those of the Air Force.

Some of the possible solutions to this problem were discussed. The first is to "beef-up" the structure to take the vibrations. With this, however, come the penalties of weight, space, and lost production time. The second method is the use of a damping drag strut on the gear. Most drag struts are rigid links, but, with the damping drag strut, the vibrations set up by the skidding might be short-lived. This second method also has the weight and size penalties and in addition would require frequent service. The third and most promising solution is that of using anti-skid brakes. These would tend to prevent sliding.

At the present time M.A.C. is setting up a laboratory test program using a simulated wing and an actual gear. With this setup, all data for possible methods of solution can be taken without damage to an actual F-101 similar to that incurred by the first test.

The fact that this problem was yet unsolved led to an interesting discussion period which closed the meeting.

ROBERT J. SHANAHAN, *Secretary*

University of Kentucky

A Student Branch of the IAS was formed at University of Kentucky on November 21. Karl O. Lange, AFIAS, Director of the Aeronautical Research Laboratory at the University, called the organization meeting after receiving requests from twelve students who wanted to join the IAS.

Under the temporary chairmanship of Professor Lange, by-laws and governing rules were discussed and adopted, and Jack Cyrus was elected Chairman of the Student Branch by acclamation.

Professor Lange was elected Honorary Chairman; Robert Reed, Vice-Chairman; and Walter Blackson, Secretary-Treasurer.

Wendell Norman was named Chairman of the Meetings Committee. The Secretary-Treasurer was instructed to submit petitions for recognition to the IAS and to the faculty of the University.

WALTER BLACKSON
Secretary-Treasurer

These members of the IAS Student Branch at Massachusetts Institute of Technology were guests of the Sikorsky Aircraft Division of United Aircraft Corp., Bridgeport, Conn., on a plant tour last fall.

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Bain, Walter G., B.S., V-P & General Mgr., Republic Aviation Corp.

Douglas, Donald W., Jr., V-P—Military Relations, Douglas Aircraft Co., Inc. (Santa Monica).

Fieldgate, Ivan O., B.Sc., Asst. Dir.—Research, Specialties, Inc.

Lischer, Alan A., B.S.C.E., Chief—Struct., Helicopter Engrg. Div., McDonnell Aircraft Corp.

Mueller, Hans F., Dr. Tech. Sc., Aero. Engr., Aircraft Div., Hughes Tool Co.

Ramey, Madison L., B.S.C.E., Chief Struct. Research Engr., McDonnell Aircraft Corp.

Truckenbrodt, Erich, Dr. Ing., Leader, Aerodynamics Dept., Ernst Heinkel Motorenbau GmbH (Germany).

Weil, Kurt H., Dipl. Ing., Asst. to Pres., The Frye Corp.

Transferred to Associate Fellow Grade

Arata, Winfield H., Jr., B.S. in Engrg., Chief Operations Engr., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Cole, Franklyn B., Jr., B.S. in C.E., Mgr., Mech. Engrg. Dept., Engrg. Lab., Lockheed Aircraft Corp. (Burbank).

Dilworth, John A., III, M.S. in Aero., Pres., Consulair.

Nicolaides, John D., M.S.E., Chief Ballistician, BuOrd., Navy Dept.

Pepper, Edward, B.S. in M.E., Proj. Engr., NADC (Johnsville).

Ribner, Herbert S., Ph.D., Research Assoc., Institute of Aerophysics, Univ. of Toronto.

Elected to MEMBER Grade

Andrews, Hal A., B.S., Supvr.—Struct. Eval. Tests, Physical Test Lab., McDonnell Aircraft Corp.

Archer, John S., Sc.D., Sr. Struct. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Bagdanovich, M. P., B.S., Consultant & R&D Engrg., Harvey Machine Co., Inc.

Bartling, William E., B.S. in Chem. Engrg., V-P—R&D, The Flying Tiger Line, Inc.

Beauregard, Robert E., B.S. in E.E., Tech. Specialist, General Electric Co. (Evendale).

Branstrom, Donald F., B.S.M.E., Engr.—Advanced Proj., General Electric Co. (Cincinnati).

Braun, Max T., B.S., Struct. Engr. "A," Proj. Stress Unit, Boeing Airplane Co. (Seattle).

Brown, Nicholas M., Design Engr., McDonnell Aircraft Corp.

Camlin, John H., Western District Mgr., Sundstrand Aviation Div., Sundstrand Machine Tool Co.

Carr, John H., M.S. in M.E., Sr. Research Engr., Jet Propulsion Lab., California Institute of Technology.

Coover, George B, B.S.G.E., Application Sales Engr., General Electric Co. (Lynn).

Crafton, Paul A., M.S., Sect. Head—Mech. Engrg., NRL (Washington, D.C.).

Dostie, Gerard L., Designer "B," Lockheed Aircraft Corp. (Burbank).

Doyle, Lawrence J., B.S.C.E., Proj. Test Engr., McDonnell Aircraft Corp.

Fannon, Marcy B., B. of Ae.E., Supvr.—Engrg. Aerodynamics, Trans World Airlines, Inc.

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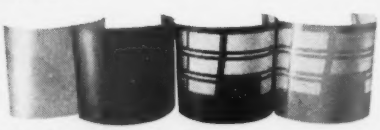

Photos (left-to-right) show chemical milling of air intake duct skins: (1) As received at USCM. (2) Covered with maskant. (3) Areas to be milled are exposed. (4) Completed part, weight reduced one-third.

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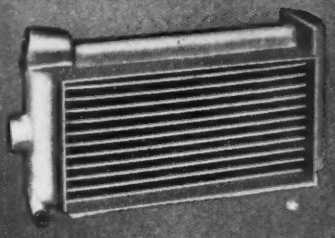

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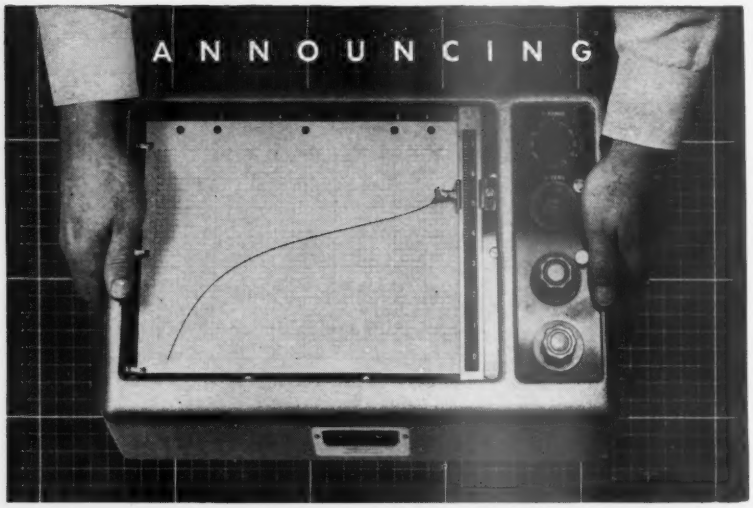

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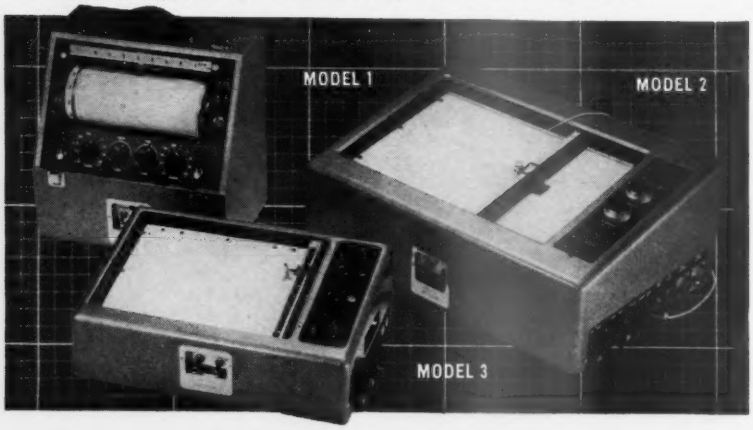

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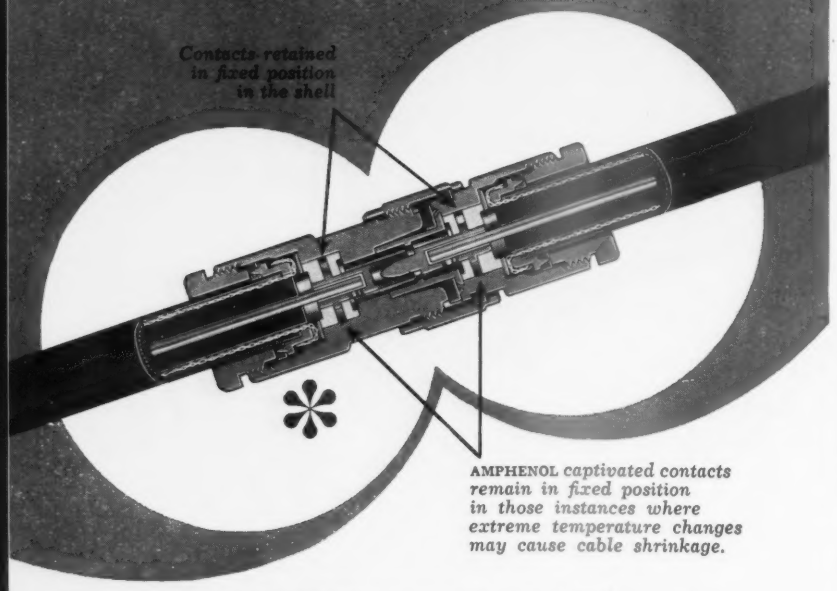

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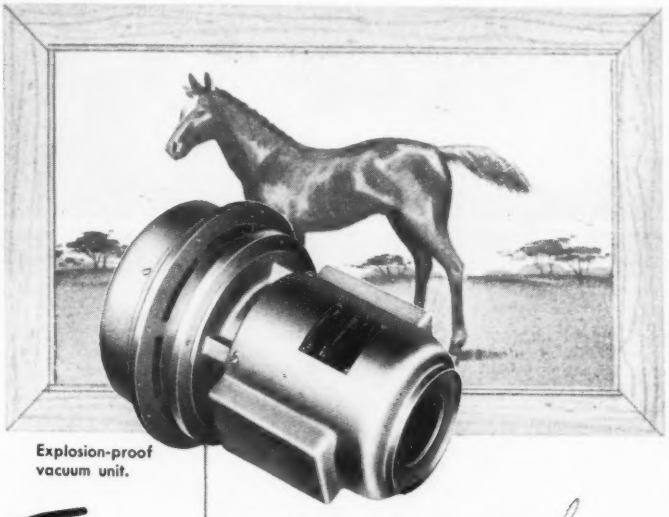
(*Continued on page 173*)



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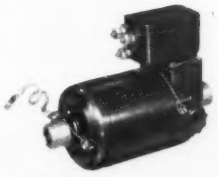

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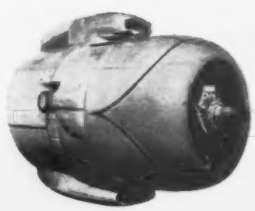

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Acoustics, Sound, and Noise

Evaluation of the Noise Field Around Jet-Powered Aircraft. Murray Kamrass and Karl D. Swartzel. (*SAE Golden Anniv. Aero. Meeting, New York, Apr. 18–21, 1955, Preprint 510.*) *Noise Control*, Nov., 1955, pp. 30–39, 54. Experimental investigation of the propagation phenomena relating the dependence of the attentuation of sound upon temperature, wind velocity, humidity, nature of nearby boundaries, and turbulence distribution between transmitter and receiver, with graphical analyses of noise effects in terms of human-tolerance criteria.

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On the Influence of the Geometry of Slender Bodies of Revolution and Delta Wings on Their Drag and Pressure Distribution at Transonic Speeds. Appendix I—Chosen Geometrical Systematic of the Form of Bodies of Revolution. Appendix II—Linear Theory: The Velocity-Distribution on Bodies of Revolution in Subsonic and Supersonic Flow. Appendix III—Contribution of the Pressure to the Drag (Linear Theory, $M_\infty = \sqrt{2}$). Appendix IV—Approximation of the Subsonic Stagnation Flow Near the Trailing Edge. Friedrich Keune and Klaus Oswatitsch. *USAF OSR TN 55-364*, 1955. 34 pp. 16 refs.

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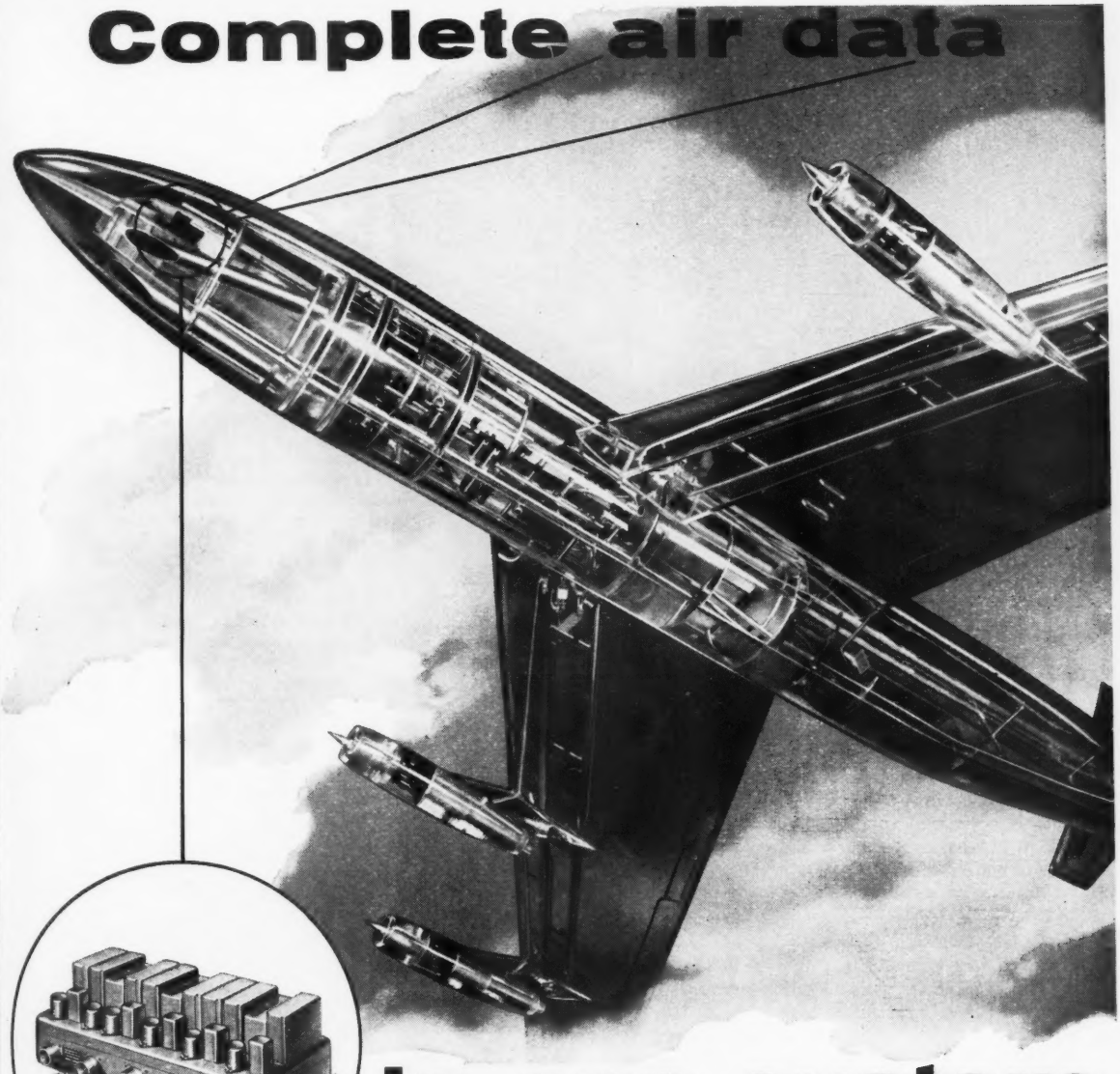

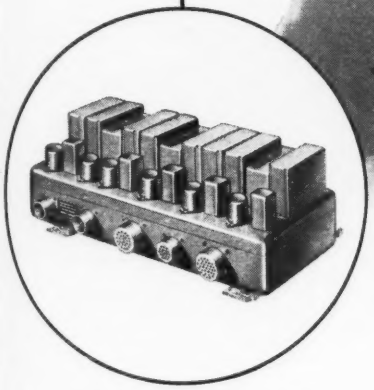

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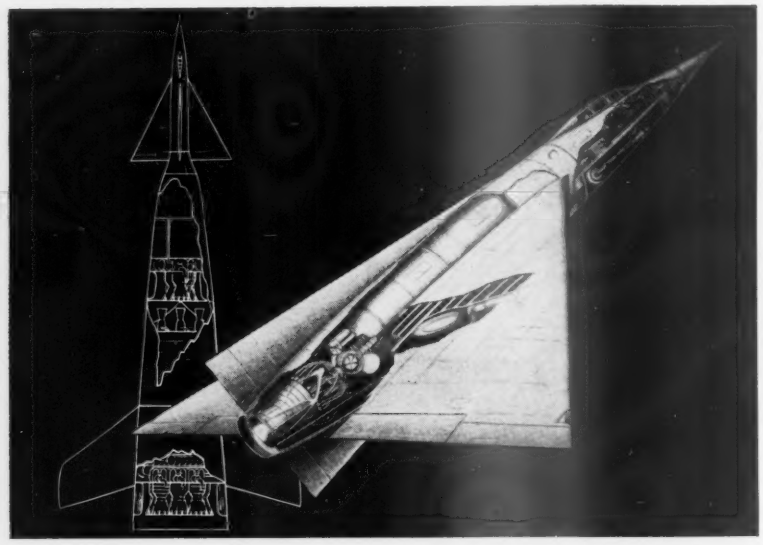

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$$\frac{e}{D}=\left(0.90+\frac{0.677}{(p_1/p_0)-1}\right)(\gamma+1.08)-3.8$$

covering the duct diameter, shock pressure, and ratio of specific heats.

The Normal Motion of a Shock Wave Through a Non-Uniform One-Dimensional Medium. R. F. Chisnell. *Proc. Royal Soc. (London), Ser. A*, Nov. 8, 1955, pp. 350–370.

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Stabilisation of the Aeroplane in Symmetric Flight at Zero or Very Small Air Speeds. Appendix I. Appendix II—Gyroscopic Yawing Couple Due to Pitching of the Aircraft. W. S. Coleman. *Aero. Quart.*, Nov., 1955, pp. 295–328. Investigation of the problem of the possible use of jet thrust as a source of lift in terms of the requirements of longitudinal symmetric motion with the automatic control force responsive to the angular displacement and velocity in pitch.

A Study of the Problem of Designing Airplanes with Satisfactory Inherent Damping of the Dutch Roll Oscillation. John P. Campbell and Marion O. McKinney, Jr. (*U.S., NACA TN 3035*, 1953.) *U.S., NACA Rep. 1199*, 1954. 18 pp. Supt. of Doc., Wash. $0.20.

Wings & Airfoils

Equations for the Loading, Section Pitching-Moment Coefficient and Center-of-Pressure Distributions on Triangular Wings Having Supersonic Leading and Trailing Edges for Various Basic Camber Distributions. Julian H. Kainer. *J. Aero. Sci.*, Feb., 1956, pp. 137–145.

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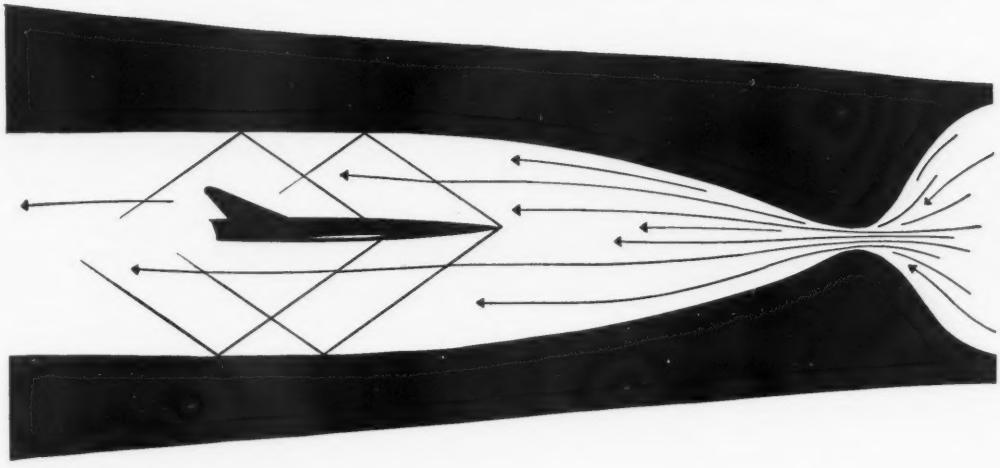

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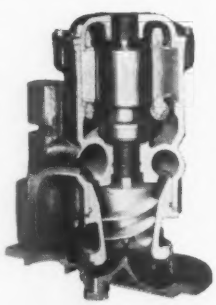

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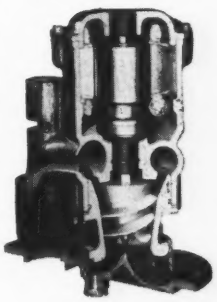

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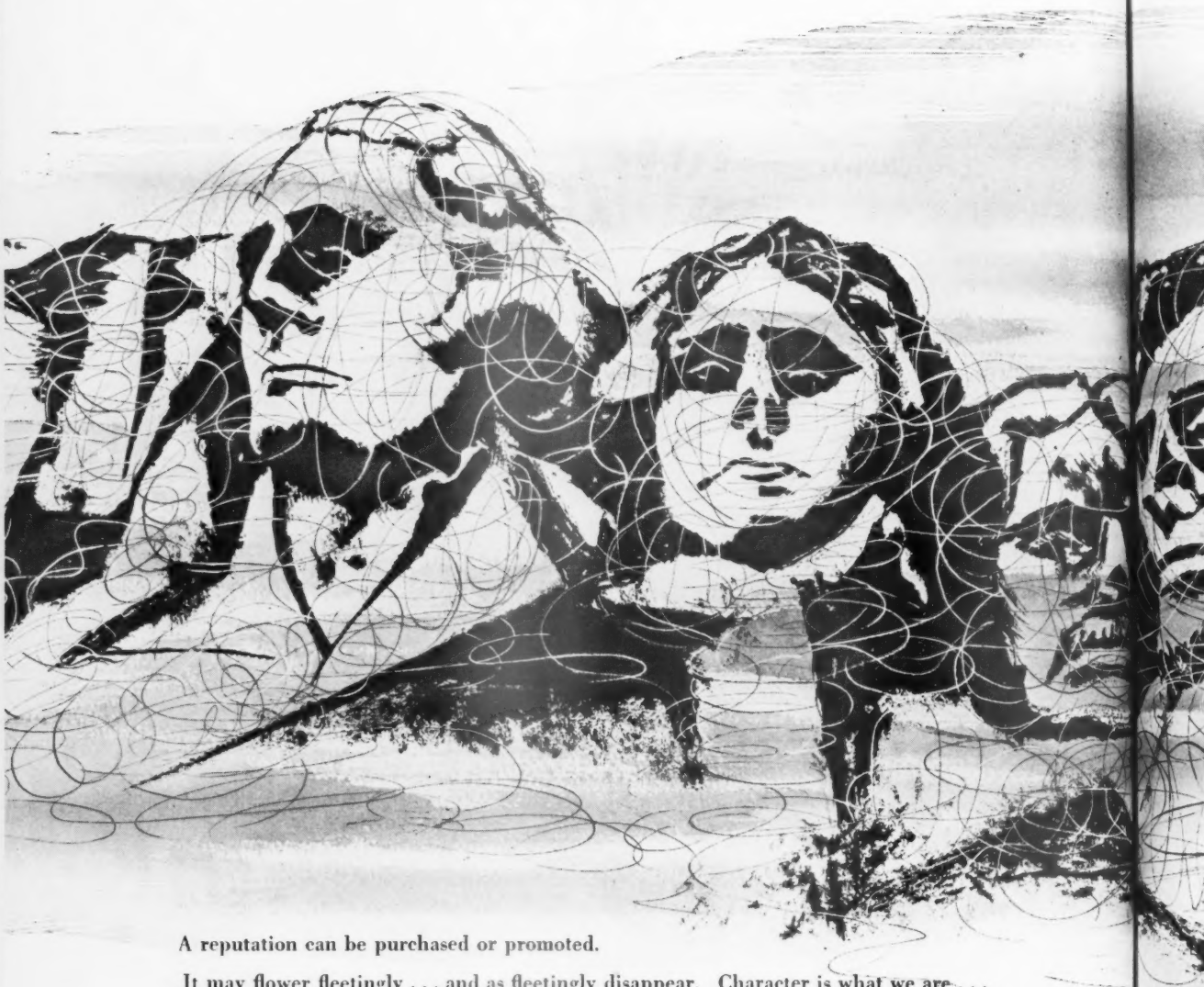

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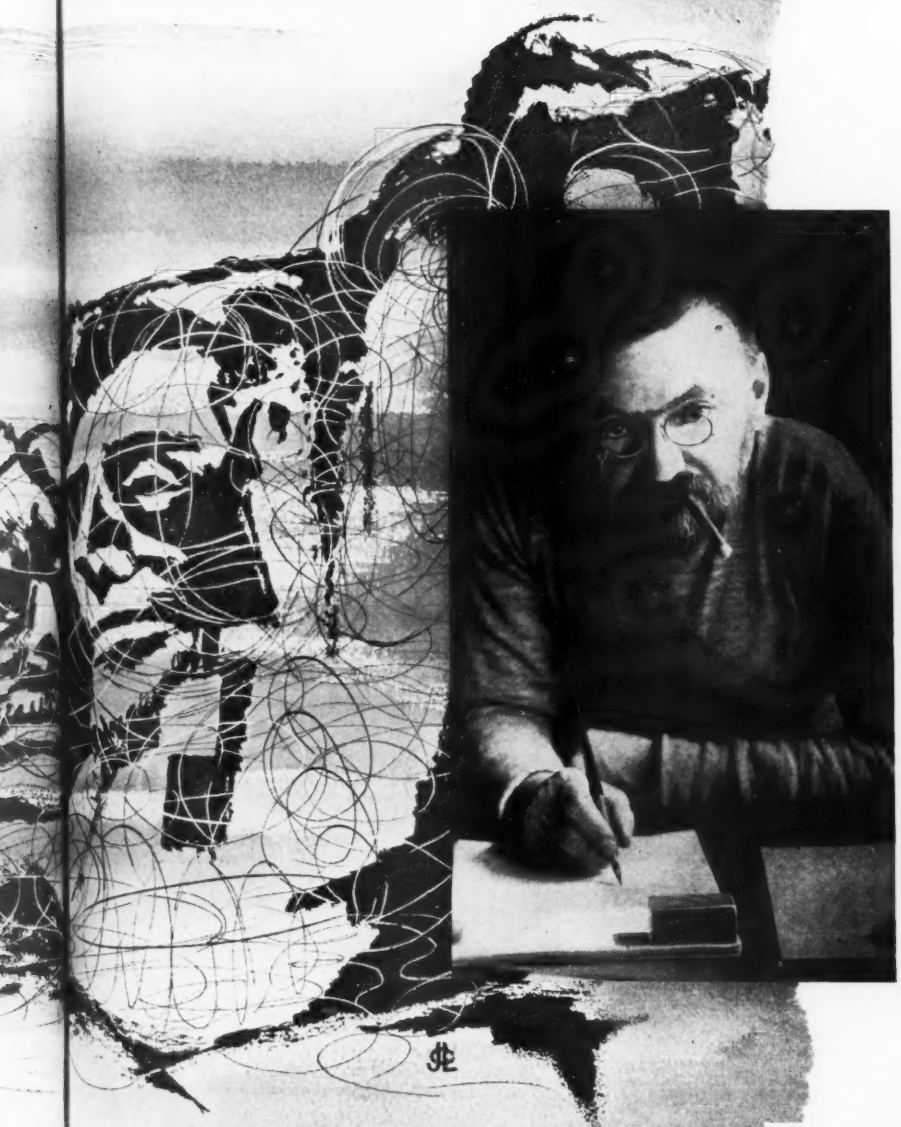

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ACOUSTICS, SOUND, AND NOISE

AIRCRAFT NOISE AS IT RELATES TO THE AIRPORT NEIGHBOR. C.E. Rosendahl. IAS Luncheon Meeting, New York, Jan. 26, 1956, Address. NATCC noise-control program covering problems of take-off, landing, and flight conditions related to basic aircraft and engine design aspects, with specifications of a system of preferential runway usage incorporating a conducting approach, landing and take-off operations over water or open areas, and procedures for maintaining maximum altitudes before landing to eliminate low, dragging, power-on approaches in populated areas.

EFFECT OF CLIMB TECHNIQUE ON JET-TRANSPORT NOISE. W.J. North. US, NACA, TN 3582, Jan., 1956. 19 pp. Theoretical investigation to determine the effect of variations in engine thrust and airspeed on sound-pressure levels heard by a ground observer, as related to the community problem of scheduled airline traffic, and to develop criteria for optimum operation consistent with safety requirements. Analytical results indicate a reduction of noise levels related directly to the reduction of either thrust or climb airspeed through a decrease of sound power radiated and through an increase of distance between source and observer.

INSTRUMENTATION FOR MEASUREMENT OF FREE-SPACE SOUND PRESSURES IN THE IMMEDIATE VICINITY OF A PROPELLER IN FLIGHT. W.D. Mace, F.J. Haney, and E.A. Brummer, US, NACA TN 3534, Jan., 1956. 16 pp. Development for harmonic analyses in aeronautical research at Mach Number 0.72 incorporating a sensing element of a capacity microphone housed in a streamlined probe for use in conjunction with an oscillator converting recorded pressure pulses into a frequency-modulated signal to be telemetered to the ground for detection and recording on magnetic tape and, subsequently, converted to a varying voltage fed into a heterodyne frequency-analyzer, with operational data on performance and accuracy levels.

INVESTIGATION OF FAR NOISE FIELD OF JETS. I - EFFECT OF NOZZLE SHAPE. II - COMPARISON OF AIR JETS AND JET ENGINES. E.E. Callaghan and W.D. Coles. US, NACA TN 3590, TN 3591, Jan., 1956. 44, 19 pp. 17 refs. Analysis of the jet noise problem and means for its suppression emphasizing nozzle designs and types of air jets, including circular, square, rectangular, and elliptical convergent types and convergent-divergent and plug-type nozzles, with the nozzle areas approximately equal to the area of the 3- or 4-in. diameter circular nozzle. Results indicate that at jet pressure ratios less than 2.2 all the nozzles have essentially the same sound field, but at higher pressure ratios only the convergent-divergent design show any appreciable reduction in sound power below that of an ordinary convergent nozzle, and at high pressure ratios all nozzles show discrete-frequency-type noises, with the convergent-divergent design eliminating such discrete frequencies during operation near its design point. In the comparison with turbojet engine operational data on noise generation, the overall sound power of air jets is well correlated by the Lighhill parameter, but the sound power radiated during afterburner operation is nonrepresentative as being somewhat lower. Spectral data further indicate the dissimilar character of of the air-jet and engine noise due to a dip in the engine noise spectra probably caused by a combination of ground reflection effects and additions to portions of the spectrum by compressor and combustion sounds.

A REVIEW OF AERODYNAMIC NOISE. L.R. Fowel and G.K. Korbacher. UTIA Rev. 8, July, 1955. 120 pp. 97 refs. Detailed results of experimental and theoretical investigations of fundamental and applicational aspects, means of suppression, technical and legal problems, and potentialities

for future research. Analysis includes a comprehensive review of the literature and the factors of: acoustic principles; the Lighthill and Proudman theories for noise causes based on subsonic disturbances and isotropic turbulence; the Lighthill, Powell, and Ribner concepts related to choked and over-choked jets; the physical structure of jets; practical considerations concerned with noise sources, locations, fields, and directionality; jet velocity, diameter, and flow density; characteristics related to Mach, Reynolds, and Strouhal Numbers; development of mechanisms of noise reduction using lower jet-flow velocity, teeth (fingers) or notches, gauze cylinders, radio swirl vanes, by-pass air and diffusers, and other suppression devices; evaluation of associated problems such as propulsion jets, nonaerodynamic noise sources, boundary-layer and wake sound levels, ground running of jet engines, noise at high altitudes, edge tones, and jet noise as a source of vibration.

AERODYNAMICS

Boundary Layer & Thermoaerodynamics

ASPECTS THERMODYNAMIQUES DE LA LUTTE POUR LA PROGRESSION DE LA VITESSE (AERODYNAMIC HEATING VERSUS SPEED; THERMODYNAMIC ASPECTS OF THE STRUGGLE). Maurice Roy. France, ONERA Pub. 77, 1955. 51 pp. 18 refs. In English and French. Investigation of the thermoaerodynamic problem as it affects high-speed flight at altitudes up to 15.5 miles in terms of: the magnitude of the upper-temperature limits for main materials and human organisms; the thermal behavior of the boundary layers; the internal and external heat exchange of the supersonic aircraft; the effects of sustained flight time; external insulation and thermal partitioning requirements; fuel protection and possible use of fuel as a coolant for cyclic cooling requiring the vaporization of transported liquids and of forced cooling systems; and the effects of aerodynamic heating on jet engine operation, specifically the cooling of the active flow of jet engines during the compression stage.

THE EFFECT OF VARIABLE FLUID PROPERTIES ON THE EQUILIBRIUM LAMINAR BOUNDARY LAYER SURFACE HEAT TRANSFER RATE AT HYPERSONIC FLIGHT SPEEDS. R. F. Probstein. Brown U. Div. Eng., WADC TN 56-2, Dec. 1955. 19 pp. 12 ref. Investigation of the basic problem for the limiting case of the boundary layer over a body of revolution in thermodynamic equilibrium, with a large stagnation enthalpy as compared with the enthalpy at the wall, under the assumption that the local composition corresponds to a gas in equilibrium at the local temperature and pressure, with the dissociation and recombination rates assumed to be very fast in comparison with the diffusion and convection rates. Analysis includes a development of a simple iterative technique using the known solutions or constant fluid properties to calculate the heat transfer influenced by the variation in fluid properties represented by the change across the boundary layer in the ratio of the product of the density and viscosity. Results indicate that the heat flux for a realistic variation of the fluid properties significantly is lower at the higher flight speeds than that predicted by constant-property solutions, with an estimating method to obtain this effect when the fluid properties are known.

EXPERIMENTAL INVESTIGATION OF LEADING EDGE SHOCK WAVE-BOUNDARY LAYER INTERACTION AT HYPERSONIC SPEEDS. J. M. Kendall, Jr. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 611. 19 pp. 14 refs. Members, $0.50; nonmembers, $0.85. OOR-sponsored tests in the GALCIT 5 x 5 in. Mach 5.8 wind tunnel on a flat plate with sharp leading edge to obtain induced pressure measurements, using orifices in a plate surface, and profiles at Mach Number, velocity, mass flow, pressure, and momentum deficiency from impact pressure surveys normal to the plate surface at various distances from the leading edge for the purpose of studying the interaction phenomena. Results indicate that the induced pressures are 25 per cent higher than predicted by the weak interaction theory; that the boundary layer and the external flow distinctly are separate for Reynolds Number as low as 6,000; that the shock-reflected expansion waves are weak; and that the average skin-friction coefficient tends toward and nearly matches the zero pressure-gradient value downstream but increases to approximately twice that value as the leading edge is approached.

HEAT TRANSFER IN SLIP FLOW. Appendix A - AN EMPIRICAL APPROACH TO SLIP FLOW. Appendix B - MATHEMATICAL DEVELOPMENT. Appendix C - MATHEMATICAL AIDS. R. L. Martino. UTIA Rep. 35, Oct., 1955, 140 pp. 47 refs. Application of the Rayleigh method to solve the energy equation for the temperature distribution for the case of a flat plate in laminar flow, using the slip and temperature jump boundary conditions of gas dynamics, with derivations of an analytical solution for the case of arbitrary constant Prandtl Number and for variable initial surface temperature and of steady flow solutions by means of a linear transformation between time and distance downstream from the leading edge as related to the Chapman-Rubesin results for the case of a constant surface temperature. Analysis includes extensive calculations for the case of a monatomic gas of 0.667 Prandtl Number in terms of the equations and boundary conditions governed by the kinetic theory. Results indicate: that the phenomena of that the phenomena of the slip or "transition" regime cannot be explained fully by the findings even though the temperature jump and slip boundary conditions are sufficient to describe it while approaching slip flow from the continuum regime; and that the recovery factor, attaining the correct limit a great distance downstream from the leading edge, tends to the limit zero as the leading

edge is approached, and the Nusselt and Stanton Numbers become functions of the Mach Number and the initial wall temperature before approaching a common limit.

A SIMPLE THEORY FOR INTERACTIONS BETWEEN SHOCK WAVES AND ENTIRELY LAMINAR BOUNDARY LAYERS. G. E. Gadd. J. Aero. Sci., Mar., 1956, pp. 225--230. Conceptual development based on simplified assumptions for the shapes of the boundary-layer velocity profiles such that the boundary layer remains laminar throughout the region of interaction, that the heat transfer to the wall is zero, and that the Prandtl Number is unity. Includes analyses of the effects of the pressure distribution at the wall, the applicability to the case of flow spearation, and a comparison with experimental results.

THE TRANSVERSE CURVATURE EFFECT IN COMPRESSIBLE AXIALLY SYMMETRIC LAMINAR BOUNDARY-LAYER FLOW. Appendix A - NUMERICAL INTEGRATION OF FIRST-ORDER MOMENTUM EQUATION FOR CONE AND CYLINDER WITH ZERO PRESSURE GRADIENT. Appendix B - SKIN FRICTION COEFFICIENT AND THE DISPLACEMENT THICKNESS. R. F. Probstein and David Elliott. J. Aero. Sci., Mar., 1956, pp. 208-224, 236. 33 refs. OSR-ONR-sponsored investigation at the Princeton U. Gas Dynamics Lab. characterizing the viscous transverse curvature effect by the ratio of the boundary-layer thickness to body radius, taking into account the Busemann and Crocco integrals of the two-dimensional energy equation in terms of validity for axially symmetric flow. Analysis includes: a reduction of the boundary-layer equations to near two-dimensional form by a generalization of the Mangler transformation to simplify the solution for the asymptotic flow regions as related to the additional term in the momentum and energy equation behaving as an external favorable pressure gradient; and a calculation of asymptotic solutions for the velocity and temperature distributions in the case of a compressible zero pressure gradient when the body shapes are given and for the velocity distribution in incompressible flow with given external velocity past the body, with the results applied to the cases of a cone, a cylinder, or a "near paraboloid" in terms of the skin-friction coefficient and the heat-transfer ratio.

DELAY OF THE STALL BY SUCTION THROUGH DISTRIBUTED PERFORATIONS. A Raspet, J. J. Cornish, and G. D. Bryant. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, 1956, Preprint 587. 19 pp. 14 refs. Members, $0.50; nonmembers, $0.85. Navy-Army-sponsored analysis of the review of the results of investigations on boundary-layer control problems, taking into account fundamental concepts as applied to the Schweizer TG3-A sailplane, the Piper L-21, AF-2, and the FI-156 (Fieseler Storch) research designs and the factors of safety, structural stress and fatigue, and stability and control.

LAMINAR SEPARATION OVER A TRANSPIRATION-COOLED SURFACE IN COMPRESSIBLE FLOW. Morris Morduchow. US, NACA TN 3559, Dec., 1955. 32 pp. 12 refs. A theoretical development of a simple practical method to calculate the separation point over a transpiration-cooled surface for a given adverse pressure gradient, Mach Number, wall temperature, and uniform coolant temperature, with a detailed numerical example to show the effects of these parameters on the separation point. Analysis includes graphical presentation of the required normal-mass-flow distribution of the coolant to maintain the actual wall-temperature ratio to the adiabatic wall temperature, and is based on an application of the von Kármán momentum integral equation in conjunction with seventh-degree velocity and stagnation-enthalpy profiles from the results of studies of laminar flow in the boundary layer, under the assumption of a uniformly maintained wall temperature with the Prandtl Number of unity and the coefficient of viscosity proportional to the absolute temperature.

PRESSURE RISE ASSOCIATED WITH SHOCK-INDUCED BOUNDARY-LAYER SEPARATION. E. S. Love. US, NACA TN 3601, Dec., 1955. 32 pp. Evaluation of results of analytical and experimental investigations of the phenomena in terms of the probable ranges of pressure rises and flow deflections and the effects of Mach and Reynolds Numbers, adverse pressure gradient, and ratio of specific heats for turbulent boundary layers as related to the influence of separation on the overall aerodynamic characteristics of complete aircraft configurations affecting the performance of individual components.

A STUDY OF THE TRANSITION TO TURBULENCE OF THE LAMINAR BOUNDARY LAYER AT SUPERSONIC SPEEDS. R. F. Probstein and C. C. Lin. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 596. 35 pp. 45 refs. Members, $0.75; nonmembers, $1.20. Review of the literature covering results of investigations of the transition phenomena and associated problems, surveying the existing data from wind-tunnel and free-flight experiments, with a general discussion on the fundamental aspects emphasizing the cases involving simple bodies such as cones, flat plates, hollow cylinders, and cone-cylinder combinations, Includes analyses of: methods used to detect transition, the conditions in the test streams, and on the surface and on the leading part of the test body, and thermal conduction factors, and of the physical mechanisms underlying possible effects; the influence of the parameters of surface cooling and heating, the body shape and pressure gradient, and surface roughness as a function of Mach Number; and of theoretical results on the extent of cooling required to stabilize effectively three-dimensional distrubances. Results indicate that small favorable pressure gradients have a strong stabilizing influence on the boundary layer, whereas adverse pressure gradients greatly increase the

cooling required for effective stabilization.

SUMMARY OF LAMINAR-BOUNDARY-LAYER SOLUTIONS FOR WEDGE-TYPE FLOW OVER CONVECTION-AND TRANSPIRATION-COOLED SURFACES. J.N.B. Livingood and P. L. Donoughe. US, NACA TN 3588, Dec., 1955. 33 pp. 25 refs. Solutions for small Mach Numbers and a Prandtl Number at the wall of 0.7, at ranges of main stream pressure gradients and rates of coolant flow through a porous wall for the cases of small temperature changes in the boundary layer along constant- or variable-temperature wall and of large temperature changes in the boundary layer along a constant-temperature wall, with a tabulation of dimensionless forms of heat-transfer and friction parameters and boundary-layer thicknesses. Results indicate that coolant emission and increased stream-to-wall temperature ratios diminish the friction and heat transfer for a constant wall temperature, that for a variable wall temperature with small temperature differences in the boundary layer, the friction is unaffected except that the heat transfer is greatly increased for increased wall-temperature gradient, and that generally transpiration cooling is much more effective for Prandtl Numbers of the order of 5.0 rather than for 0.7.

Control Surfaces

THE JET FLAP. I - THE BASIC PRINCIPLES. II - SOME AERONAUTICAL CONSIDERATIONS. I. M. Davidson. J. RAeS, Jan., 1956, pp. 25--41; Discussion, pp. 41--50. 12 refs. Review of NGTE powered-lift investigations on the large Fowler-flap-like behavior of jet-flapped airfoils based on an aerodynamic resynthesis of the lifting and propulsive means, taking into account the supercirculation phenomena, lift and thrust of a two-dimensional wing, problems with wings of finite span, three-dimensional effects, and factors affecting maximum lift including gusts and engine failures, with an appraisal of trends and potentialities.

Fluid Mechanics & Aerodynamic Theory

THE APPLICATION OF THE ELECTRIC-TANK ANALOGY TO TWO- AND THREE-DIMENSIONAL PROBLEMS IN LINEARIZED AERODYNAMIC THEORY. W. B. Brower, Jr. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5506 (OSR-TN-55-471). Dec. 15, 1955. 103 pp. 28 refs. Development of the analogical calculator, providing representation of boundary-conditions and aerodynamic quantities and incorporating the transverse-flow method to solve rapidly and accurately the integral differential equation of the linearized lifting theory, with a discussion of basic computational principles, relative merits, and potentialities, and with construction details including circuit design, model geometry, and electrode spacing. Experimental solutions include the cases of a flat plate inclined to the free stream, lift of camber sections, the flapping of an airfoil, and an airfoil with basic symmetrical thickness at zero lift as representative of two-dimensional problems and of the effects of incidence, camber, and camber and twist for a flat-plate wing and the low-aspect-ratio wing of parabolic planform illustrative of three-dimensional problems.

A DISCUSSION ON MAGNETO-HYDRODYNAMICS. Edward Bullard, Moderator, and others. Proc. Royal Soc. (London), Ser. A, Dec. 29, 1955. pp. 289-427. 66 refs. Results of theoretical and experimental investigations to develop and apply principles of fluid mechanics. Partial contents: An Instability of Laminar Flow of Mercury Caused by an External Magnetic Field, B. Lehnert. Magneto-Hydrodynamic Oscillations of a Rotating Fluid Globe, T. G. Cowling. Hydromagnetic Turbulence. I - A Deductive Theory; II - An Elementary Theory, S. Chandrasekhar. Magneto-Hydrodynamic Waves in Incompressible and Compressible Fluids, A. Baños, Jr. The Structure of Magneto-Hydrodynamic Shock Waves, W. Marshall. Waves in a Heavy, Viscous, Incompressible, Electrically Conducting Fluid of Variable Density, in the Presence of a Magnetic Field, R. Hide. Some Engineering Applications of Magneto-Hydrodynamics, J. H. Shercliff.

THE LARGE-SCALE STRUCTURE OF HOMOGENEOUS TURBULENCE. Appendix A - EVALUATION OF SOME ISOTROPIC SURFACE INTEGRALS. Appendix B - THE FORM OF INTEGRAL MOMENTS OF SOLENOIDAL TENSORS. G. K. Batchelor and I. Proudman. Philos. Trans. Royal Soc. (London), Ser. A, Jan. 5, 1956, pp. 369-405. Extension of the Proudman-Reid theoretical results for isotropic turbulence with zero fourth-order cumulants to the study of the two-fold problem of finding general large-scale kinematical structures which can persist in time, through being unchanged by dynamic processes, and of finding the particular structure that is relevant to wind-tunnel turbulence, taking into account the concepts of Batchelor, Birkhoff, Lin, Loitsiansky, and others. Includes analyses of the basic related factors of: the hypothetical convergent integral moment at an initial instant; the generation of power-law forms of velocity cumulants at large values of the separation; general dynamics of the large-scale motion; and the special case of isotropic turbulence.

PROGRESS IN RESEARCH ON HIGH SPEED FLOW; A SURVEY OF ADVANCES AND PROBLEMS IN THE STUDY OF HIGH SPEED FLOW. I - NORMAL SUPERSONIC FLOW. II - TRANSONIC FLOW. III - HYPERSONIC FLOW. Maurice Holt. Aircraft Eng., Nov., Dec., 1955, Jan., 1956, pp. 371-373, 392-395, 21-24. 21 refs. Results of experimental and theoretical investigations tracing research trends up to about Mach 25 for missile and rocket flights including such factors

as the breakdown of the linearized theory of supersonic flows at hypersonic speeds, the use of the inviscid small disturbance equations for calculation of steady three-dimensional hypersonic flow past a cylindrical body of small maximum thickness, measurements of pressure on flat plates in hypersonic viscous flow, and the relevance and applicability of wind-tunnel and shock-tube techniques.

BASE PRESSURE STUDIES IN RAREFIED SUPERSONIC FLOWS. L.L.Kavanau. J. Aero. Sci., Mar., 1956, pp. 193-207, 230, 35 refs. OAR-ONR-supported investigation at U. of Calif. to obtain base pressure data in terms of the influence of high altitudes for a blunt-based body of revolution of a simple cone-cylinder configuration, with measurements including the slip flow regime. Analysis includes: calculations of support interference effects due to the relative size of the sting diameter and length as compared to the model diameter and the effects of heat transfer; data on the base pressure coefficient in free molecular flow; description of testing techniques and apparatus used; and a comparison to previous theoretical and experimental investigations. Results indicate the decrease in base pressure at decreasing Reynolds and increasing Mach Numbers due to the completely laminar character of the boundary-layer and critical wake region.

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF SURFACE ROUGHNESS ON THE DRAG OF A CONE-CYLINDER MODEL AT A MACH NUMBER OF 2.48. Appendix - LAMINAR SUBLAYER CALCULATIONS. J.H.T.Wade. UTIA Rep. 34, Sept., 1955. 72 pp. 25 refs. Tests on a 20° cone-cylinder model of overall fineness ratio equal to 13, at Reynolds Numbers of 3.0×10^6 per foot based on free stream conditions, with turbulent skin-friction calculations, as compared to similar Chapman and Kester results, by direct force measurements using an internal strain-gage balance, covering the 6--10,000 microin. roughness range based on the average peak-to-valley height. Results indicate that the rough cylinder shows no increase in friction over that of the smooth cylinders for roughness below the 800--1,000 microin. range and a rapid increase with roughness height beyond the critical roughness in agreement with the Nikuradse findings for incompressible flow; that the critical roughness range is about 30° lower than the value obtained experimentally in incompressible flow using wall values of the flow parameters for comparison; and that the study of the boundary-layer profile at the start of the cylinder permits an evaluation of a local skin friction coefficient at that point, which is used to compute the thickness of the laminar sublayer by means of the von Kármán approach.

ON THE INFLUENCE OF THE GEOMETRY OF SLENDER BODIES OF REVOLUTION AND DELTA WINGS ON THEIR DRAG AND PRESSURE DISTRIBUTION AT TRANSONIC SPEEDS. Appendix I - CHOSEN GEOMETRICAL SYSTEMATIC OF THE FORM OF BODIES OF REVOLUTION. Appendix II - LINEAR THEORY: THE VELOCITY-DISTRIBUTION ON BODIES OF REVOLUTION IN SUBSONIC AND SUPERSONIC FLOW. Appendix III - CONTRIBUTION OF THE PRESSURE TO THE DRAG (LINEAR THEORY $M_\infty = \sqrt{2}$). Appendix IV - APPROXIMATION OF THE SUBSONIC STAGNATION FLOW NEAR THE TRAILING EDGE. Friedrich Keune and Klaus Oswatitsch. USAF OSR TN 55-364, 1955. 34 pp. 16 refs. Application of the Area Rule to study the characteristics of the flow around delta and swallow-tailed wings in the transonic range, as related to the flow about equivalent bodies of revolution, with calculations of the upper and lower critical Mach Numbers near unity using the linear theory and the Oswatitsch-Sjödin formula, and a determination of Mach 1 by means of the parabolic method. Analysis includes: an evaluation of the suitability of geometrical systems of bodies of revolution in terms of the linear range; and particular examples of wings equivalent to these bodies, with data on the sonic flow and results given in a general form by the transonic similarity. Results indicate that the drag of the afterbody is practically equal to the whole supersonic drag of this part; that even the linear supersonic theory is valid for all supersonic Mach Numbers; that the small subsonic region on the tip at the upper critical Mach Number has no appreciable influence; and that the Area Rule requires a correction if the wings or bodies have ends that are too blunt.

A PRELIMINARY STUDY OF THE DETAILS OF THE FLOW FIELD ABOUT A FLAT PLAT AT HYPERSONIC SPEEDS. A.G.Hammitt. Princeton U. Dept. Aero. Eng. Rep. 327, Nov. 1, 1955. 31 pp. 19 refs. Experimental investigation in the helium hypersonic wind tunnel operating at speeds up to Mach 15 to determine an appropriate flow model and to appraise the value of former theoretical models. Analysis includes; test data on the interaction region from optical and pitot measurements of pressure on the plate surface and of the shock position; and calculations of the inviscid and viscous flow fields to construct the flow near the shock wave by use of rotational characteristics and a small leading-edge wedge angle. Results show large static pressure gradients between the shock wave and the plate surface, but no signs of a uniform inviscid flow region between the boundary layer and the shock wave.

A SECOND-ORDER SHOCK-EXPANSION METHOD APPLICABLE TO BODIES OF REVOLUTION NEAR ZERO LIFT. Appendix A - POWER SERIES REPRESENTATION OF FLOW ABOUT BODY OF REVOLUTION. Appendix B - EVALUATION OF PRESSURE GRADIENT DOWNSTREAM OF CORNER OF BODY OF REVOLUTION. Appendix C - EXTENSIONS OF THE APPROXIMATE METHOD. C.A.Syvertson and D.H.Dennis. US, NACA TN 3527, Jan., 1956. 57 pp. 25 refs. Development of a theoretical method, applicable

when the hypersonic similarity parameter based on nose fineness ratio is near one, to derive expressions defining the pressures on noninclined bodies by use of the characteristics theory in combination with properties of the flow predicted by the generalized shock-expansion method and extended to inclined bodies to calculate the normal-force and pitching-moment derivatives at zero angle of attack. Analysis includes: comparisons with other theoretical predications and experimental results of pressure distributions for non-inclined bodies and of normal-force derivatives and centers of pressure at zero angle of attack for inclined bodies; measurements for cone-and ogive-cylinders with fineness ratios of 3--17 tested at Mach 3.00--6.28, corresponding to a 0.43--2.09 range of values for the hypersonic similarity parameter; and an evaluation of the relative merit and accuracy of the predictions obtained.

LOIS DE LA RÉFLEXION DES ONDES DE CHOC DANS LES ÉCOULEMENTS PLANS NON STATIONNAIRES. Henri Cabannes. France, ONERA Pub. 80, 1955, 29 pp. Study of the shock-wave phenomena governed by a uniform transfer as a factor of instability of the motion of compressible fluids in nonstationary plane flow in terms of: the characteristics of the regular reflection; the flow after and behind the reflected shock applied to the case of pseudo-stationary plane flows; and the establishment of laws of reflection of Mach as applied to the cases of dihedrons of any given or nul angle, taking into account the Lighthill linearized equations for an infinitely small angle, an incident infinitely weak or strong shock, orthogonal and stationary reflection, and the transition from the regular reflection to that of Mach. Analysis includes precise numerical calculations of the finite variations of the flow characterizing the magnitude resulting from the slightest modification of speed or of the direction of the incident shock wave.

METHOD OF INTEGRATION FOR SUPERSONIC FLOW BEHIND AN ATTACHED SHOCK-WAVE. I - GENERAL DESCRIPTION OF THE PROBLEM AND METHOD OF SOLUTION. II - QUASI-AXIALLY SYMMETRIC FIELDS. III - METHODS OF INTEGRATION FOR CONICAL FIELDS. IV - NUMERICAL EXAMPLES - GENERAL REMARKS ON THE MOST CONVENIENT ORDER OF APPROXIMATION. Luigi Broglio. Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 3 (AF EOARDC TR 1), 1955. 114 pp. Development for the general three-dimensional case using the three components of velocity and entropy as the unknowns derived by direct integration and not simultaneous to the other functions, taking into account the Ferri procedure for a cone without axial symmetry, with a comparison to the mode of analysis using the method of characteristics.

STRUKTURA PLASKIEJ FALI UDERZENIOWEJ (TWO-DIMENSIONAL SHOCK WAVE STRUCTURE). Włodzimierz Prosnak. Rozprawy Inżynierskie (Warsaw), No. 3 1955, pp. 361-385. 21 refs. In Polish, with summaries in English and Russian. Review of the results of investigations of steady plane shock wave in a viscous heat conducting gas based on the equations of the mechanics of continuous media as compared to the kinetic theory and experimental data. Includes analyses of the factors influencing the type of variability of hydrodynamic parameters, including viscosity and heat conductivity, and the phenomenon of local decrease of entropy accompanying the overall increase of entropy, in terms of the elements of a heat conducting gas related to nonisolated systems of the second law of thermodynamics.

Internal Flow

DESIGN CRITERIA FOR AXISYMMETRIC AND TWO-DIMENSIONAL SUPERSONIC INLETS AND EXITS. Appendix A - ESTIMATED PERFORMANCE OF SINGLE-OBLIQUE-SHOCK INLETS. Appendix B - ESTIMATED PERFORMANCE OF DOUBLE-OBLIQUE SHOCK INLETS. J.F. Connors and R.C. Meyer. US, NACA TN 3589, Jan., 1956. 42 pp. Graphical development for single- and double-oblique-shock inlets and for isentropic and two-dimensional surfaces having theoretically focused Mach lines for Mach Numbers up to 4.0, with nondimensional geometric contours having corresponding local Mach Numbers and flow-angle variations, and with all solutions carried from the freestream Mach Number to a local Mach Number of unity, taking into account limitations on the amount of the compressive flow turning that can be utilized with isentropic inlets, a compression limit based on shock-structure requirements coming into effect at Mach 1.5, and an all-external-compression inlet with a mass-flow ratio of unity limited to a theoretical pressure recovery of 0.685 at Mach 4.0. Analysis includes a comparison of optimum performance for several types of conventional inlets over a wide range of supersonic Mach Numbers to illustrate the relative capability of the isentropic inlet.

EXPERIMENTAL AND ANALYTICAL INVESTIGATION OF SECONDARY FLOWS IN DUCTS. Appendix A, Appendix B - RESOLUTION OF BOUNDARY-LAYER VELOCITIES INTO COMPONENTS NORMAL AND TANGENTIAL TO MAIN-FLOW STREAMLINES. H.Z. Herzig and A.G. Hansen. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 593. 62 pp. 12 refs. Members, $0.35; nonmembers, $0.75. NACA study of the internal flow phenomena in curved ducts, considered as three-dimensional boundary-layer flows having components normal to the main stream direction, using smoke flow visualization procedures, and extending the work of Mager, Hansen, Loos, and Sowerby on the laminar boundary layers over a flat plate to regions of small turning to obtain exact solution for general streamline paths without restrictions, using tables

of special Blasius similarity parameter functions to compute boundary-layer cross flows, with the streamline paths at various positions in the boundary layer described for thick and thin layers. Analysis includes examples of cross-channel flows and cross-channel flow effects, with experimentally observed results compared to theoretical predictions.

AN EXPERIMENTAL INVESTIGATION OF FLOW SEPARATION IN A NOZZLE AT HIGH MACH NUMBERS AND LOW DENSITY. N. B. Tucker. UTIA Rep. 33, Aug., 1955. 71 pp. 37 refs. Tests in the 5 x 5 in. supersonic wind tunnel to obtain evidence of a stable form of flow separation in a two-dimensional wedge nozzle having a 1 in. throat radius at area ratio Mach Numbers above 4, with the separation occurring without any abrupt change in static pressure gradient and without a shock wave being associated with the phenomena. Analysis includes: measurements for the detection of air condensation and of the pitot, static, and stagnation pressures, the stagnation temperature, and specific humidity of the inlet air; methods used to suppress and control nozzle flow separation, taking into account the effect of nozzle throat radius, the use of an adjustable throat, surface roughness in supersonic flow, and flow in three axisymmetrical square-throat supersonic nozzles; and detailed descriptions of instrumentation and testing techniques, including schlieren photographic flow visualization. Results, as compared to those of previous investigations, indicate that the precise measurement of Mach Numbers up to 5 is feasible with available instrumentation; that air condensation is present in flow above Mach 5 and is eliminated by heating the inlet air, with the inlet stagnation temperatures required to remove the condensation being higher than those calculated by theory and experiment; and that flow separates in the round-throat two-dimensional wedge nozzle block at Mach Numbers above 3.8, with the use of a square-throat axisymmetric nozzle not eliminating this separation, but with the onset of separation in the two-dimensional nozzle delayed to Mach 5.7 by the use of surface roughness on the flow surfaces of the nozzle.

AN EXPERIMENTAL STUDY OF CENTRIFUGAL PUMP IMPELLERS. Appendix I - BLADE DESIGN. Appendix II - MEASUREMENT OF LOSS AND RELATIVE VELOCITY. A. J. Acosta and R. D. Bowerman. CIT Hydrodynamics Lab. Rep. E-19.8, Aug., 1955. 44 pp. 13 refs. The results of ONR-sponsored investigations of internal flow problems of impellers analyzed in terms of overall characteristics, velocity profiles, pressure distributions, and associated measurements, and of three-dimensional flow requirements to develop design criteria of head, torque, and efficiency data. Includes: calculations of static pressure distributions on the vanes of 12.5° and 20° impellers at several flow rates, and of relative total head loss contours for 12.5°, 15°, 20°, and for three-dimensional impellers at the impeller exits, mid-radius postions, and inlets; and detailed description of laboratory facilities, instrumentation, and testing apparatus and techniques.

LIFT HYSTERESIS AT STALL AS AN UNSTEADY BOUNDARY-LAYER PHENOMENON. F. K. Moore. US, NACA TN 3571, Nov., 1955. 32 pp. 12 refs. Approximate analysis of the rotating stall of compressor blade rows taking into account the Magnus lift of a rotating cylinder on a 6:1 elliptic airfoil at the angle of attack for maximum lift under the assumption of small perturbations neglecting the distributed vorticity in the wake beginning at the separation point defined by zero shear in the case of steady flow, with a calculation of the loop flows for small reduced frequency of oscillation when the concept of viscous "time lag" is applicable only for harmonic variation of angle of attack with time at mean conditions other than maximum lift.

Performance

WARUM WESPENTAILLENFORM? DIE FLÄCHENREGEL; EINE NEUE MÖGLICHKEIT ZUR ABMINDERUNG DES WIDERSTANDSANSTIEGES IM TRANSONIKGEBIET. Dietrich Fiecke. Flugwelt (Wiesbaden), Dec., 1955, pp. 640--644. In German. Evaluation of the development, relative merits, and potentialities of the "Area Rule" concept in aircraft design to reduce the drag increase in the transonic range, with aerodynamic performance data on speed gains in the case of fighter craft.

Stability & Control

DIRECTIONAL STABILITY OF TOWED AIRPLANES (DIE SEITENSTABILITÄT EINES GESCHLEPPTEN FLUGZEUGES). W. Söhne. (Ing.-Arch., No. 4, 1953, pp. 245-265.) US, NACA TM 1401, Jan., 1956. 53 pp. 12 refs. Translation. Theoretical investigation of the lateral dynamic stability problem when using a single towline with a derivation of the equations of motion in terms of cable moment coefficients, the influence of cable length, flight attitude, and configuration parameters on the stability in towed flight, taking into account variations of the lift coefficient, flying weight, angle of climb, rolling moment due to sideslip by a varied dihedral, vertical-tail surface area, damping in roll, coupling at the lower side of the fuselage, and of the position of the towing point in a horizontal direction.

EXPERIMENTAL INVESTIGATION AT LOW SPEED OF EFFECTS OF FUSELAGE CROSS SECTION ON STATIC LONGITUDINAL AND LATERAL STABILITY CHARACTERISTICS OF MODELS HAVING 0° AND 45° SWEPTBACK SURFACES. William Letko and J. L. Williams. US, NACA TN 3551, Dec., 1955. 45 pp. 10 refs. Tests on mid-wing airplane models at the Langley Aero. Lab. for

an angle of attack range from -4° beyond maximum lift, of wings alone, at angle of sideslip of 0° and ± 5° and at 0°, 10°, 20°, and 26°, through a sideslip range from -20° to 20°. Results indicate that the main effects on the stability characteristics of models at low angles of attack are caused by the direct contributions of the fuselage; that at high angles of attack the wing-fuselage interference or sidewash with the tail decreases the tail contribution to the directional stability; that for the complete configuration the fuselage cross section has little effect on the range of linearity of the curves of yawing moment against the sideslip angle; and that generally the shallow-fuselage configurations are the least stable longitudinally, and the deep-fuselage designs are the least stable directionally.

THE LONGITUDINAL MOTION OF A SPECIAL AIRPLANE BY THE DISCONTINUOUS AUTOMATIC VELOCITY CONTROL. Akira Azuma. J. Japan Soc. Aero. Eng., Oct., 1955, pp. 247-255. In Japanese. Application of the results of the Flügge-Lotz investigation of problems of missile position control using an analogous method to study the motion of an aircraft controlled by an elevator and ailerons and equipped with two gyroscopes to register the rolling and pitching angular velocity, with the control function having an unfeeling zone in which the elevator is restored to the neutral position.

METODY TEORII STATECZNOŚCI RUCHU (METHODS OF THE THEORY OF STABILITY OF MOTION). Maciej Bieniek. Rozprawy Inżynierskie (Warsaw), No. 3, 1955, pp. 327-358. 13 refs. In Polish, with summaries in English and Russian. Analysis includes: basic concepts and general characteristics of the approaches used to study stability problems; Lyapunov theorems for steady and unsteady motion; and evaluations of the stability theorems in the first approximation and of the criteria of Routh-Hurwitz and Nyquist.

Wings & Airfoils

FLOW STUDIES OF THE LEADING EDGE STALL ON A SWEPT-BACK WING AT HIGH INCIDENCE. Joseph Black. J. RAeS, Jan., 1956, pp. 51-60. 10 refs. Use of detailed pressure distribution measurements over the leading edge, the liquid film technique, yawmeter traverses to calculate the boundary-layer flow, a wool-tuft grid, and a spin detector to determine the vorticity regions to investigate experimentally flow in the separation region over the outer span of the wing taking the form of a "ram's horn" vortex and originating from the junction on the leading edge of the inboard "short" and the outboard "long" separation bubbles.

FLOW STUDIES ON DROOPED-LEADING-EDGE DELTA WINGS AT SUPERSONIC SPEED. W. H. Michael, Jr. US, NACA TN 3614, Jan., 1956, 29 pp. Experimental investigation using vapor-screen, pressure-distribution, and ink-flow tests at Mach 1.9 on the delta wings having semiapex angles of 15°, 22.5°, and 31.75° with 10 per cent and 20 per cent of the semispans drooped 15° in streamwise sections to determine separated regions of vorticity existing along the upper surfaces of the wings. Results indicate that the separated regions on the wings having 10 per cent and 20 per cent of the semispans drooped are similar to one another; that integrated pressure distributions for equal angles of attack show the loadings on the wings having 20 per cent of the drooped semispans are less than those for the wings having 10 per cent of the drooped semispans; and that, generally, compared with undrooped delta wings, the drooped-loading-edge wings show no particular advantage from the standpoint of preventing separation.

REMARK ON THE THEORY OF LIFTING SURFACES (SULLA TEORIA DELLE SUPERFICI PORTANTI). Aldo Muggia. (Acad. Sci. Torino, Atti, 1952-1953.) US, NACA TM 1386, Jan., 1956, 11 pp. Translation. Study of the problem of lift on any thin wing of arbitrary plan form based on the Weissinger method idealizing the vortex system for a rectangular wing in terms of the aerodynamics of a lifting surface, in itself an idealization of an actual wing, having the simple physical property that it departs but slightly from the flat surface that is considered as being immersed in an incompressible fluid of a given density and as having a given free-stream pressure and velocity, with the impinging stream assumed to be directed along and having the same sense as the positive x-axis in a right-handed Cartesian coordinate system.

THE TRANSONIC CHARACTERISTICS OF 36 SYMMETRICAL WINGS OF VARYING TAPER, ASPECT RATIO, AND THICKNESS AS DETERMINED BY THE TRANSONIC-BUMP TECHNIQUE. W. H. Nelson, E. C. Allen, and W. J. Krumm. (US, NACA RM A53I29, 1953.) US, NACA TN 3529, Dec., 1955, 131 pp. Experimental investigation in the Ames 16-ft. high-speed wind tunnel of the effects of planform taper on the aerodynamic characteristics on wings of aspect ratio of 4 with taper ratios of 0, 0.2, and 0.5; of 3 with taper ratios of 0.14, 0.33, and 0.6; and of 2 with taper ratios of 0.33, 0.5, and 0.72; and on NACA 63A00X airfoil sections with thickness-to-chord ratios of 8, 6, 4, and 2 per cent, at a Mach range of 0.6--1.1 and a Reynolds range of about 1.4--2.0 million. Results, presented in comprehensive graphical form, indicate that the greatest effect of taper on the lift-curve slope occurs for the wing configuration having the highest aspect ratio and the thinnest section, with the effect diminishing as the aspect ratio decreases and/or the thickness increases; thus, in general, increasing taper ratio increases the overall center-of-pressure travel for all the wings between subsonic to supersonic speeds.

RECENT DEVELOPMENTS IN THE THEORY

OF WING-BODY WAVE DRAG. Harvard Lomax and M. A. Heaslet. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 617. 23 pp. 25 refs. Members, $0.65; nonmembers, $1.00. Analysis of the Jones-Whitcomb Supersonic Area Rule in terms of its range of applicability and of the basic concept of the Transonic Area Rule to calculate wing-body interference effects, with an evaluation of other methods based on linearized theory and of recent results based on the non-linear, small-perturbation transonic equation, and with comparisons between theoretical and experimental data.

REDUCTION OF SUPERSONIC WAVE DRAG FOR WING-FUSELAGE COMBINATIONS AT ZERO LIFT. R. M. Licher. Douglas Rep. SM-19436, Nov., 1955. 13 pp. Application of a design criterion to combine fixed-wing geometry of elliptic plan form and optimum thickness distribution with modified fuselages to obtain minimum wave drag, with the reductions in thickness drag being largest for low values of wing reduced aspect ratio.

AEROELASTICITY

AN APPLICATION OF THE METHOD OF EQUIVALENCE TO THE DEFLECTION OF A TRIANGULAR PLATE. D. E. Ordway and Carlo Riparbelli. J. Aero. Sci., Mar., 1956, pp. 252-258. Experimental investigation using the Broglio approach to determine the elastic behavior of a thin solid delta wing of an arbitrary sweep angle and rectangular chordwise cross section under any given normal loading and of a 45° swept wing under a uniform load, as in the case of such problems as flutter or divergence velocity.

CONSTRUCTION AND TESTING OF A DOUBLY-FLEXIBLE FLUTTER MODEL OF A DELTA WING. M. M. Chen. MIT ASRL TR 54-2, June, 1955. 57 pp. A demonstration of the design feasibility for a beam-network model structure to match a given set of influence coefficients for the XF-92A 60° delta wing with the correct external shape and mass distribution taken into account to obtain measurements for the material frequencies and mode shapes. Analysis includes: calculations for the effects of camber or chord bending, vibration, and flutter under the root conditions of cantilever, free-to-roll, and free-to-heave, and a comparison with experimental findings for the full-scale airplane, for which reasonable agreement is indicated. Results show that no flutter was encountered up to about 80 m.p.h. for any root condition studied in terms of the model design of a 20:1 velocity ratio, but with a modified model wing having an elevon, numerous flutter conditions occur at different elevon frequencies for each root condition.

DEFLECTION MEASUREMENTS ON A 45° SWEPT AND TAPERED RECTANGULAR TUBE. G. L. Belcher, Australia, ARL Rep. SM. 228, June, 1955. 19 pp. Results of tests on a DTD 390 aluminum model representing the structural portion of a swept and tapered wing with ribs parallel to the line of flight, with the measured deflections compared to the predictions obtained by the Hall method, and with a determination of the influence coefficients for eight points of the tube subjected to a concentrated load at each of these points in turn under the conditions allowing freedom of roll about the axis of symmetry by fitting the external ribs with axles running in self-aligning ball races mounted on a supporting framework rested on the floor; includes provisions for corrections of deflection regions from dial gages.

THE DIVERGENCE OF SUPERSONIC WINGS INCLUDING CHORDWISE BENDING. M. A. Biot, J. Aero. Sci., Mar., 1956, pp. 237-251, 271. 15 refs. NAVORD-sponsored investigation at CAL of the static aeroelastic stability problem covering the leading edge instability, the amplification factor for lift and overturning moment of a wedge, the stability of the biconvex leading edge, an approximate treatment of the three-dimensional problem, a general numerical method to determine the stability of the cantilever wing as a function of Poisson's ratio and the magnitude of the deformation, and the possible effects of aerodynamic nonlinearity.

EFFECT OF RIB FLEXIBILITY ON THE VIBRATION MODES OF A DELTA WING AIRCRAFT. W. D. Kroll. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 585. 14 pp. Members, $0.50; nonmembers, $0.85. NavBuAer-sponsored analysis at NBS based on the findings of the Southwest Res. Inst. investigation to determine the applicability of the prediction of critical flutter speed reduction obtainable from experimental models according to chordwise stiffness parameters, with calculations, using the consistent-deformation method of influence coefficient matrix, of the modes and frequencies for the basic wing and for modifications of one or two ribs outboard of fuselage removed and stiffness of ribs outboard reduced one-half or nine-tenths. Analytical results indicate that the frequencies and modes of the modified shapes differ little from those of the basic wing and that changes similar to the modifications would not appreciably affect the vibrational characteristics of the delta configurations.

EFFECTS OF STRUCTURAL FLEXIBILITY ON GUST LOADING OF AIRCRAFT. II - DYNAMIC STRESSES IN SWEPT-WING AIRPLANES. Appendix A - DERIVATION OF THE GENERALIZED MASSES AND FORCES. Appendix B - DETERMINATION OF TRANSIENT STRESSES. Appendix C - EFFECT OF NACELLE FLEXIBILITY ON WING STRESSES. Appendix D - EFFECT OF VIBRATORY DOWNWASH AT THE HORIZONTAL TAIL. Appendix E - THE CONVERGENCE OF TRANSIENT STRESS METHODS. Appendix F - INVESTIGATION OF OPTIMUM NACELLE LOCATION. A. A. Kirsch,

J. M. Calligeros, and K. A. Foss. USAF TR 54-592, Part 2, Aug., 1955. 189 pp. 17 refs. Development of a simplified numerical method to determine transient stresses in swept-wing aircraft after entry into a gust, taking into account the effects of the pitching motion and of the unsteady downwash at the tail. Results of the calculations indicate that more degrees of freedom are required in the analysis of gust loads on flexible swept wings than for unswept wings; and that the alleviation of gust loads commonly attributed to flexible swept wings always is cancelled at least partially by the increased pitching motion of the aircraft.

EXPERIMENTAL PRESSURE DISTRIBUTIONS ON OSCILLATING LOW ASPECT RATIO WINGS. W. R. Laidlaw and R. L. Halfman. J. Aero. Sci., Feb., 1956, pp. 117-124, 176. 14 refs. NavBuAer-sponsored investigation in the MIT 5 x 7 1/2 ft. Low-Speed Flutter Wind Tunnel at a constant air speed of 90 m. p. h., with the models mounted on the MIT-NACA airfoil oscillator for shaking the wing in sinusoidal motions at frequencies between 2--15 cycles per sec., to measure the distribution of lifting pressure over the surface of low aspect ratio wings oscillating in an incompressible flow by means of a small light weight barium titanite pressure transducer during the simple harmonic pitching and vertical translation motions of the wings to obtain numerically integrated list and pitching moment distributions and total lift and pitching moment coefficients; tests on rectangular, sweptback, and delta plan forms in addition to a wing-tip tank configuration measured in both the wind tunnel and in still air. Analysis includes: evaluations of the relative merits of the Reissner high aspect ratio theory for accurate aeroelastic and dynamic stability calculations in the aspect ratio range above two; the Laidlaw low aspect ratio pressure distribution theory for measurements on rectangular wings; the Lawrence-Gerber low aspect ratio theory on chordwise lift distributions and total lift and pitching moment coefficients for rectangular delta wings; the Garrick-Voss very low aspect ratio theory for delta wings considered unsuitable for aspect ratios above one; and the Ashley high aspect ratio sweptback wing theory considered totally unsuitable in the low aspect ratio range; and of experimental results on the "end-plate" effect of wing tip tanks producing higher pressure amplitudes particularly near the wing tips but with the phase angles essentially the same as for wings without tanks.

FLEXURE VIBRATION OF UNIFORM BEAMS SIMPLY SUPPORTED AT EQUAL INTERVALS - NORMAL MODES AND FREQUENCIES. C. M. Cheng. GALCIT OSR TN-55-235, July, 1955. 21 pp. Derivation of a simple formula to compute the frequency of each normal mode, expressible in terms of elementary functions in a closed form, taking into account the frequency spectra for the case of an infinitely long beam on infinite number of supports. Includes comparison to the relevance of other investigations; application of the results to such complex problems as the flutter of panels and thin cylinders; and a demonstration of the analytical technique.

THE FLUTTER OF A BUCKLED PLATE IN A SUPERSONIC FLOW. Y. C. Fung. GALCIT OSR-TN-55-237, July, 1955. 36 pp. Solution, under the assumption of small reduced frequency and linearized aerodynamic theory, based on the Galerkin method of the problem for a thin elastic plate having the edges hinged to supports perfectly rigid and fixed in space, with a sufficiently large compressive load assumed to act in the plane of the plate to cause buckling, were the plate free from all tractions normal to the plate surface, considered as the nonlinear element related to the compressive load on the lateral deflection. Includes analyses of both the linear small amplitude flutter modes about equilibrium positions and the nonlinear finite amplitude modes and of theoretical and unsolved questions. Results indicate that the static stability of a panel in supersonic flow has no direct bearing on its dynamic stability about an equilibrium configuration dependent on aerodynamic damping and based on infinitesimal perturbations.

THE FLUTTER OF SIMPLY SUPPORTED RECTANGULAR PLATES IN A SUPERSONIC FLOW. J. G. Eisley. GALCIT OSR TN-55-236, July, 1955. 62 pp. 11 refs. Analysis of the problem using the linearized aerodynamic theory for the case of small deflections of a single rectangular plate of finite aspect ratio in a supersonic airstream as an extension of the Hedgepeth-Budiansky-Leonard treatment, following an approach similar to that of Shen, with the flutter mode described by a series expansion in terms of the normal modes of oscillation of the plate in a vacuum, under the simplifying assumptions of harmonic motion and approximation equations of the strip theory, in which the flow over any narrow strip parallel to the flow is represented by a two-dimensional solution, and of a quasi-steady equation, in which all terms containing second and higher orders of the reduced frequency are neglected. Includes calculations of flutter boundaries for plates of varying aspect ratio for $M = \sqrt{2}$ and $M = 2$.

FORCED VIBRATIONS OF A RIGID CIRCULAR PLATE ON A SEMI-INFINITE ELASTIC SPACE AND ON AN ELASTIC STRATUM. G. N. Bycroft. Philos. Trans. Royal Soc. (London), Ser. A, Jan. 5, 1956, pp. 327-368. 11 refs. Theoretical analysis to determine the two functions of frequency as the effective in-phase and out-of-phase components of displacement for the case of the unloaded circular plate in terms of its impedance with four degrees of freedom and the effect of plate loading by the addition of mass or moment of inertia, using dimensionless variables to decrease the number of parameters, taking into account the fundamental study of Lamb on the propagation of elastic waves, that of Reissner for the cases of the harmonically

forced vertical translation of a rigid circular plate attached to elastic half-space and of torsional oscillations of an elastic half-space with simplified boundary conditions, that of Reissner and Sagoci for the similar problem using a system of oblate spheroidal coordinates, and that of Marguerre for wave propagation in elastic strata. Includes the factors of vertical and horizontal translation, rotation about a vertical and horizontal axis, and damping.

MEASUREMENT OF THE AERODYNAMIC FORCES ON OSCILLATING AEROFOILS; A SURVEY OF TECHNIQUES USED FOR THE EXPERIMENTAL DETERMINATION OF AERODYNAMIC DERIVATIVES FOR FLUTTER CALCULATIONS. Appendix - DIRECT MEASUREMENT OF THE FORCE VECTORS. W.G. Molyneux. Aircraft Eng., Jan., 1956, pp. 2-10. 10 refs. Relative merits of measuring techniques applied to the calculation of the eight relevant coefficients for a rectangular wing oscillating in modes of vertical translation and uniform pitch. Includes the methods of free, forced, and flutter oscillations and of pressure plotting.

PISTON THEORY - A NEW AERODYNAMIC TOOL FOR THE AEROELASTICIAN. Holt Ashley and Garabed Zartarian. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 610. 22 pp. 20 refs. Members, $0.65; nonmembers, $1.00. Representative applications to simplify the solutions of high-speed, unsteady aeroelastic problems by means of aerodynamic techniques based on the physical model concepts of Lighthill and Hayes and as developed by Landahl using expansions in powers of the thickness ratio and the inverse of the flight Mach Number in terms of theoretical predictions of a point-function relationship between the local pressure on the surface of a wing and the normal component of fluid velocity produced by the motion of the wing, with the computation of generalized forces in aeroelastic equations such as the flutter determinant always reduced to elementary integrations of the assumed modes of motion. Analysis includes essentially closed-form solutions for the bending-torsion and control-surface flutter properties of typical-section airfoils at high Mach Numbers, demonstrating the increasingly important influence of thickness and profile shape as a function of the increasing Mach Number; an iterative procedure to obtain improved flutter eigenvalues through the successive introduction of higher order terms in the thickness ratio and the inverse flight Mach Number; a review of other applications to unsteady supersonic problems such as gust response and rapid maneuvers of elastic aircraft; and an evaluation of the potentialities of the piston theory in aerodynamic-thermoelastic interaction problems, with recommendations for future research.

A PRELIMINARY INVESTIGATION OF THE EFFECTS OF FREQUENCY AND AMPLITUDE ON THE ROLLING DERIVATIVES OF AN UNSWEPT-WING MODEL OSCILLATING IN ROLL. L. R. Fisher, J. H. Lichtenstein, and K. D. Williams. US, NACA TN 3554, Jan., 1956, 29 pp. Unsteady motion analysis using a model with separable wing and tail assembly oscillating in roll through a range of frequencies and amplitudes at an angle of attack of zero degree and at one frequency and amplitude for two higher angles of attack, with the model tested as a fuselage alone, a fuselage-tail combination, a fuselage-wing configuration, and as a complete configuration. Results indicate that the fuselage-tail combination is the only configuration exhibiting yawing moment due to rolling of any appreciable magnitude, with the wing-interference effect on the tail contribution estimatable accurately by means of existing steady-state theory; that the frequency or amplitude has no noticeable effect on the magnitude of the damping in roll for the model or any of its components at an angle of attack of zero degree; and that the rolling derivative measured by the oscillation tests generally are consistent at low angles of attack with the derivatives determined by conventional rolling-flow steady-state tests, but at a high angle of attack the oscillatory yawing moment due to rolling for the fuselage-wing configuration differs from that obtained under steady-state conditions.

THE SOLUTION OF AEROELASTIC PROBLEMS ON WINGS OF ARBITRARY PLAN FORM BY MATRIX METHODS. J. J. Foody and L. Reid. J. RAeS, Dec., 1955, pp. 843-846. Analytical formulation in terms of the symmetric case, in which the problem of the maneuvering margin is due to the aeroelastic effect, and the antisymmetric case dealing with the rolling effectiveness and the reversal speed for aileron controls.

STRIP THEORY FOR OSCILLATING SWEPT WINGS IN COMPRESSIBLE SUBSONIC FLOW. W. Eckhaus. Netherlands, NLL Rep. F. 159, Oct., 1955. 14 pp. 12 refs. Theoretical derivation using an asymptotic expansion under the assumption that the aspect ratio and the frequency of oscillation is not too small to analyze the general case of a lifting surface of arbitrary shape. Includes methods to calculate the pressure distribution from the integral equation of the strip theory related to the Possio-type equation. Results indicate that in the limiting case of incompressible flow the theory leads to results indentical with earlier results.

SYNTHESIS OF BEAM-NETWORK STRUCTURES FOR LOW-ASPECT-RATIO FLUTTER MODELS. Appendix A - DERIVATION OF STIFFNESS SUBMATRICES FOR A TWO-BAY LATTICE NETWORK. Appendix B - DERIVATION OF FLEXIBILITY SUBMATRICES FOR A THREE-BAY LATTICE NETWORK. Appendix C - EXPRESSIONS OF SUBMATRICES FOR MODEL WITH SIX CONTROL POINTS. M. M. Chen and S. I. Gravitz. MIT ASRL TR 54-1, Mar., 1955. 90 pp. 24 refs. Methods for designing one-dimensional and lattice network structures to reproduce given sets of flexibility

influence coefficients at preassigned control points over the structure, with a development of an iterative procedure to solve the nonlinear relations in the unknown stiffnesses of the numbers of a lattice network used as elastic frameworks of the flutter models in the design and construction of static models related to the wing of the XF-92A.

THE TORSIONAL VIBRATIONS OF A CLASS OF THIN, TAPERED, SOLID WINGS. Appendix I - ANALYSIS FOR A PLATE OF VARYING THICKNESS. Appendix II - CHORDWISE SECTIONS OTHER THAN RECTANGULAR. Appendix III - ST. VENANT FREQUENCY FOR TAPERED WINGS, ω St. V_t. E. A. Frost. Gt. Brit., ARC CP 218, 1955. 22 pp. BIS, New York. $0.65. Analysis, using a technique similar to that of Reisner and Stein, for the case of wings of doubly symmetrical chordwise section having linear variation of chord and parabollic variation of thickness, taking into account the effect of constraint against inherent axial warping, with graphical data on the frequencies of symmetrical and anti-symmetrical modes of vibration for a range of values of the aspect and taper ratios.

AIRPLANE DESIGN

STOL AIRPLANES - A NEW APPROACH TO AIR TRANSPORT. R.A.Darby. Aero.Eng.Rev., Mar., 1956, pp. 48-54. Developmental analysis of the Short Take-Off and Landing fixed-wing design in terms of civil and military operational characteristics, with an evaluation of the applied forced circulation, vectored slipstream principle, variable thrust incidence, and adapted direct turbojet support; includes a discussion of relative merits, potentialities, and trends.

COMPUTERS

ELECTROANALOGIC METHODS. II - SOLUTION OF CONTINUUM-MECHANICS PROBLEM BY CONTINUOUS-TYPE CONDUCTIVE PROCEDURES. T.J.Higgins. Appl. Mech.Rev., Feb., 1956, pp. 49-55. 314 refs. Comprehensive review of the literature including experimental factors of elasticity, thermodynamics, hydrodynamics, and aerodynamics, with provisions for error compensation.

ELECTRONICS

THE PROBLEM OF COOLING ELECTRONIC EQUIPMENT IN HIGH PERFORMANCE AIRCRAFT. N.A.Carhart. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 612. 19 pp. Members, $0.50; nonmembers, $0.85. Analysis of the present and expected natural, varied, and modified environment of aircraft and of means to achieve greater efficiency by a more accurate definition of heat-transfer requirements related to better coordination between aircraft and electronic manufacturers and performance criteria of aircraft and electronic components.

EQUIPMENT

ACCESSORY DRIVE TURBINES FOR AIRCRAFT AND MISSILES. O.E.Balje. Aero. Eng. Rev., Mar., 1956, pp. 60-67. Simplified analysis of the adaptability of conventional single-stage turbine designs to accessory drives in terms of excessively high required rotational speeds, impulse and reaction turbine efficiency as a function of velocity ratio and design geometry of air passages, the relationship between specific speeds and the ratio of the effective nozzle area to the impeller diameter, and drag pump peak efficiencies and pressure coefficients as functions of the ratio of drag factors, with drag turbine performance charts and test values.

INSTRUMENTS

INVESTIGATIONS OF THE PROPERTIES OF CORRUGATED DIAPHRAGMS. W.A.Wildhack, R.F.Dressler, and E.C.Lloyd. ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13-18, 1955, Paper 55-A-181. 39 pp. 19 refs. Correlation of pressure deflection characteristics of the diaphragms using dimensional analysis based on experimental results for various sizes, materials, thicknesses, and shapes; derivation of linear shell equations for combined bending and stretching effects, with lateral loading terms for rotationally symmetrical shell in appropriate independent and dependent variations suitable for complicated meridial shapes, and with boundary conditions for practical diaphragm applications; analysis includes a method for the solution of the system of equations by means of an electronic digital computer.

PULSATING FLOW MEASUREMENT BY VISCOUS METERS, WITH PARTICULAR REFERENCE TO THE AIR SUPPLY OF INTERNAL-COMBUSTION ENGINES. Appendix I - OSCILLATIONS AND DAMPING OF MANOMETER LIQUID. Appendix II - MAXIMUM ALLOWABLE ACCELERATION. Appendix III - LAMINAR FLOW THROUGH A PASSAGE OF TRIANGULAR SECTION. L.J. Kastner and T.J.Williams. IME Proc., No. 26, 1955, pp. 419-432; Discussion, pp. 433-437; Communications, pp. 437-440; Authors' reply, pp. 441-444. 31 refs. Experimental evaluation of design and performance of viscous meters with its stream directed through a number of narrow passages across which the pressure difference is

measured, with the Reynolds Number kept so low that the flow is laminar.

MATERIALS

CURRENT PROBLEMS OF THE METALLURGY OF TITANIUM. II - THE REDUCTION OF TITANIUM TETRACHLORIDE WITH MAGNESIUM. III - THE PRODUCTION OF TITANIUM BY FUSED SALT ELECTROLYSIS. W.J.Kroll. (Metall, Berlin, No. 9/10, 1955, pp. 366-376) Gt. Brit., RAE Lib. Transl. 554, Oct., 1955. 29 pp. 66 refs. Metallurgical analysis of chemical, physical, purification, and applicational properties in terms of cost and production requirements, with a comprehensive review of the literature.

INFLUENCE OF TEMPERATURE ON CREEP, STRESS-RUPTURE, AND STATIC PROPERTIES OF MELAMINE-RESIN AND SILICONE-RESIN GLASS-FABRIC LAMINATES. W.N.Findley, H.W.Peithman, and W.J.Worley. US, NACA TN 3414, Jan., 1956. 71 pp. 14 refs. Results of static-tension, static-compression, tension-creep, and time-to-fracture tests at temperatures up to 600° F. indicating the weakening of mechanical properties of the laminates directly related to an increase in temperature, with the creep data considered as additional evidence showing the percent of strain increase from one given time to another, and referred to as "creepocity," is independent of stress and represented by an equation based on an activation-energy theory and a power function of time describing the effect of stress, time, and temperature. The analysis indicates the possibility that no creep occurs at temperatures below -10° F. for the melamine-resin laminate and below -119° F. for the silicone-resin type.

ON THE THERMAL ASPECT OF FATIGUE. A.M.Freudenthal and J.H.Weiner. J.Appl.Phys., Jan., 1956, pp. 44-50. 32 refs. WADC-supported investigation of the mechanism of thermal fatigue analyzed in terms of the factors of heat release in slip processes, quasi-steady state for moving heat sources, temperature level on slip-planes, moving heat source in an infinite medium and between insulating planes, and temperature and thermal stress intensity in fatigue stressing of a particular material such as aluminum. Results indicate a close interrelationship between slip and fatigue damage such that the highly localized temperature and associated thermal stress gradients in front of active slip planes, resulting from the conversion into heat of the work in slip of the resolved shear stress, are of sufficient severity to account for the initiation of micro-cracks parallel to the slip planes if the slip under repeated stress cycles is concentrated into striations.

ON THE SOLUTION OF PROBLEMS OF DYNAMIC PLANE ELASTICITY. J.R.M.Radok. Australia, ARL Rep. SM.230, July, 1955. 16 pp. Evaluation of the complex variable approach to the study of dynamic equations with the stress function providing the solution of a fourth-order partial differential equation reduced to a generalized biharmonic form of the type occurring in anisotropic elasticity for wave calculations and expressed in terms of two analytic functions, corresponding to two types of waves occurring in elastic media, defining the stress and displacement components leading to a reduction of boundary-value problems into the complex function theory. Applications of the results include analyses of the problems of the moving Griffith crack and of moving dislocations.

MISSILES

BALLISTIC MISSILE PERFORMANCE. J. W. Reece, R.D.Joseph, and Dorothy Shaffer. Cornell Aero. Lab. Rep., Sept. 16, 1955. 25 pp. Development of a semianalytic method for calculating the range of one-stage ballistic rocket-propelled surface-to-surface missiles to obtain simple approximation of the fundamental complex trajectory problem applicable to a 50--500 nautical mile range, taking into account solutions of the equations of motion, hypothetical flight-in-vacuum values, and corrections for the effective drag. Principal assumptions include: that the missile behaves as a mass point ignoring stability factors; that it follows a great circle path ignoring the Coriolis acceleration due to the earth's rotation; that flight is under NACA standard atmospheric conditions; that the vertical launching and impact take place at sea level, with the trajectory between launching and cut-off programmed in order to obtain a constant rate of change of the flight path angle with respect ot time; that the thrust and rate of mass ejection are constant; and that the corrections for drag are small as compared to the quantities for which they are applied.

ÜBER EINE SIMULTANE ANALYTISCHE INTEGRATION DER BEWEGUNGSGLEICHUNGEN EINES GEFLÜGELTEN GERÄTES IM ÜBERSCHALLGLEITFLUG. H.J.Kaeppeler. Astronautica Acta, Fasc. 4, 1955, pp. 166-170. In German. Analytical integration of the simultaneous differential equations of motion of a winged body in arrested-engine, nonpowered supersonic glide without a retarding wake, under the assumption that the angle of inclination of the trajectory tangent and the lift-to-drag ratio remain constant. Includes data on an arbitrary atmosphere and the variation of gravity to altitude, with relations for the calculation of the velocity of variation with altitude and time dependent on the motion in the trajectory. .

PHOTOGRAPHY

A HIGH-SPEED CAMERA FOR THE PHOTOGRAPHY OF SHOCK-WAVE OSCILLATIONS IN A

WIND TUNNEL. D.W.Holder, R.J.North, W.G. Standring, and J.S.T.Looms. Gt. Brit., ARC R&M 2901 (Aug., 1949), 1955. 15 pp. BIS, New York. $1.15. Development to permit study of quasi-stationary phenomena adapted for either the schlieren or the shadowgraph methods at camera speeds up to 2,000 frames per sec. with exposures of the order of 1 microsec.; includes sample photographs of oscillations occurring when the critical Mach Number is exceeded at low Reynolds Number on an EC 1250 airfoil.

POWER PLANTS

Jets and Turbine

AN ACCURATE CALIBRATION OF A DERWENT 8 GAS TURBINE. Appendix A - OCRRECTION OF OBSERVED RESULTS TO STANDARD CONDITIONS AS SPECIFIED BY THE ENGINE MANUFACTURER. R.V.Pavia. Australia, ARL Mech. Eng. Note 202, Aug., 1955. 20 pp. Test-bed instrumentation and detailed measurement of thrust to determine performance levels, air-intake and jet pipe temperatures, engine speeds, pressure parameters, fuel consumption, and compressor delivery.

REVERSE THRUST, VERTICAL LIFT, AND SIDE FORCE BY MEANS OF CONTROLLED JET-DEFLECTION. Leonard Meyerhoff and S.A. Meyerhoff. IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 624. 25 pp. 24 refs. Members, $0.65; nonmembers, $1.00. USAF-supported investigation of the application of propulsive jet deflection as a means of augmenting the control of jet aircraft particularly at low speeds in terms of take-off and landing requirements when using thrust reversal as the braking technique to decrease markedly the landing run, and of its use for side forces for jet steering, jet enforced lift to permit flight below the normal stalling speed, and thrust modulation. Results indicate that the minimum flight speed with jet lift is dependent primarily on the ratios of static-thrust to weight and lift to drag; that the time elapse between the touchdown and the use of rated negative thrust partially nullifies the effect of jet reversal; and that rapid in-flight deceleration for a transport could be advantageous as a method for a fast slow-down in the event of emergency.

TESTS ON A TYPICAL WHITTLE COMPRESSOR. A.Simons and C.K.Roberts. Gt.Brit., ARC R& M 2913 (July, 1952), 1955. 10 pp. BIS, New York. $0.75. Results on design and performance levels of the compressor used in the W2/700 series of jet engines, indicating that at 1,500 ft. per sec. the overall pressure ratio or total head is 4.27 and the adiabatic efficiency 75.6 per cent at a mass flow of 36.3 lb. per sec., and that the overall efficiency falls rapidly from 79.6 per cent at 1,400 ft. per sec. to 75.6 per cent at 1,500 ft. per sec. due to choking of the outer half of the impeller eye, with the maximum diffuser efficiency rated at approximately 80 per cent at a tip speed of 1,500 ft. per sec.

Rocket

LOW-FREQUENCY COMBUSTION INSTABILITY IN BIPROPELLANT ROCKET MOTORS - EXPERIMENTAL STUDY. M.Barrere and A. Moutet. Jet Propulsion, Jan., 1956, pp. 9-19. 12 refs. Development of methods to measure the short-time response from circular and rectangular section chambers, with calculations of the frequency related to chamber size and design characteristics, mean pressure of the flame body as well as the fluctuating pressures, and the nature of the fuels used, with the parameters of fuel mixture ratios, injection overpressure, and length and section of connections considered as secondary in nature. Analysis includes: the fundamental aspects of the Crocco distinctions between normal and unstable combustion; and a comparison of theoretical and experimental results.

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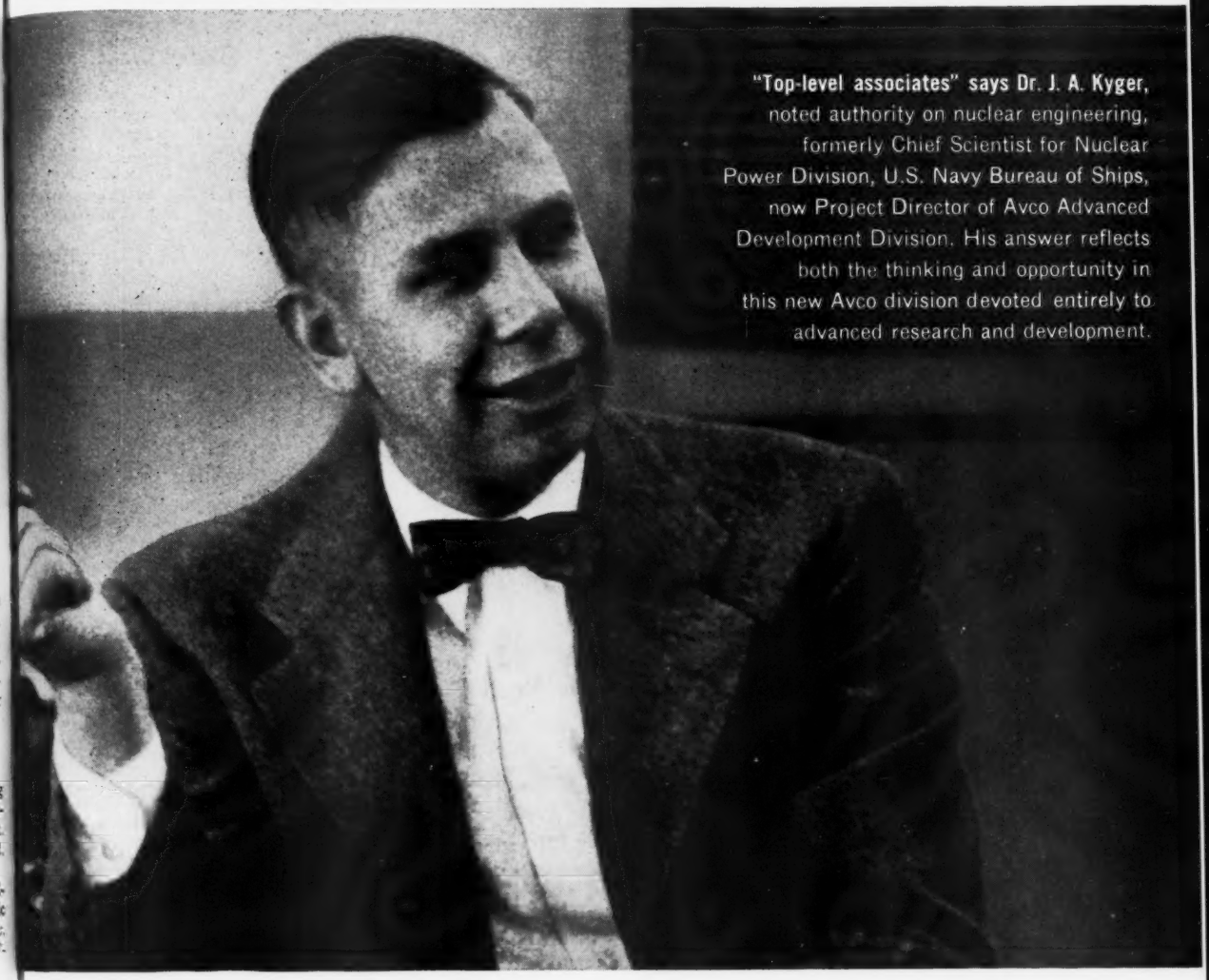

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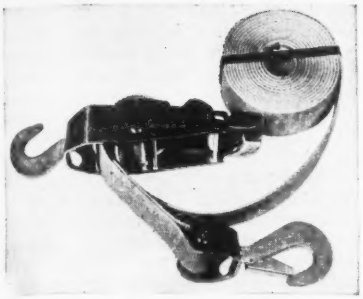

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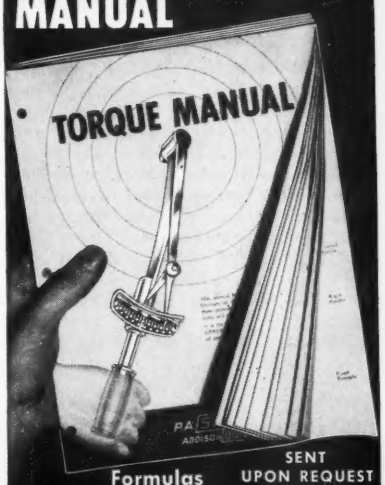

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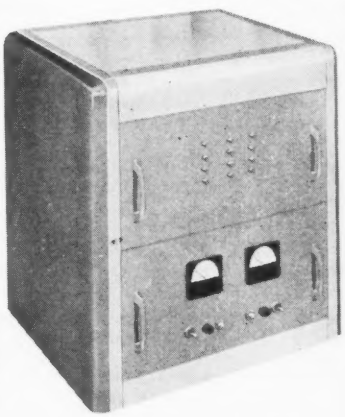

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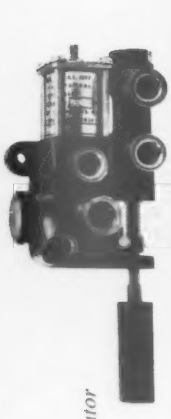

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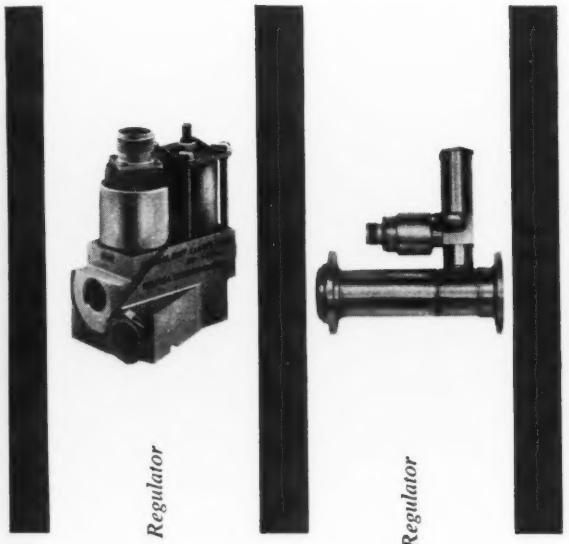

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MISSILE SYSTEMS

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Note on a Null Method for the Direct Measurement of Pressure Coefficients.

(*Continued on page 173*)

Aeronautical Reviews — BOOKS

AIRPLANES

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Aircraft Badges & Markings. Harold B. Pereira. London, Adlard Coles, Ltd.; New York, John de Graff, Inc., 1955. 48 pp., illus. $1.50.

Pocket-size volume containing in full color the national markings, fin flashes, and air-line badges adopted throughout the world. Includes 'Registration Code Letters' of each country.

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Transistors and Other Crystal Valves. T. R. Scott. London, Macdonald & Evans, Ltd.; New York, Essential Books, Inc., 1955. 258 pp., illus., diagrs. $7.20.

This is an attempt at a comprehensive condensation of the profusion of material on crystal valves. Written by the Managing Director of Standard Telecommunication Laboratories, Ltd., it gives engineers who may have to use transistors a clear picture of the general stage of transistor development at the present time. It is intended for the user of these devices rather than for the engineer engaged in developing or designing them, and it is aimed particularly at informing him of the transistor's potentialities and limitations. The volume contains 65 illustrations and a bibliography of 277 references.

Contents: (1) Introduction. (2) Crystal Imperfections. (3) *p-n* functions. (4) Point-Contact Devices. (5) Operating Temperatures—Output—Life. (6) Applications—Circuitry—Testing. (7) Special H.F. Transistors. (8) Choice of Semiconductors. (9) Conclusions—The Future.

Basic Electrotechnics. B. L. Goodlet. 2d Ed. London, Edward Arnold, Ltd., 1955. 277 pp., illus., diagrs., tables. $5.25.

A textbook for degree students, this is the second edition of a work first published in 1951. The general revision is expanded by 30 pages and includes a new chapter on transient phenomena. The author has been Professor of Electrical Engineering in the Universities of Cape Town and Birmingham.

Contents: Table of Dimensions. (1) Steady Electric Currents. (2) Electrostatic Fields, Condensers and Dielectrics. (3) Electrodynamics. (4) The Calculation of Magnetic Fields. (5) Alternating Currents. (6) Transient Phenomena. (7) Maxwell's Equations and Electromagnetic Waves.

METALS & ALLOYS

Symposium on Effect of Temperature on the Brittle Behavior of Metals; with Particular Reference to Low Temperatures. Atlantic City, June 28-30, 1953. (Special Technical Publication No. 158.) Philadelphia, American Society for Testing Materials, 1954. 474 pp., illus., diagrs., figs. $2.25.

Contents: Introduction, A. L. Tarr. Brittle Failures in Ships and Other Steel Structures, K. K. Cowart. Analysis of Brittle Behavior in Ship Plates, M. L. Williams. A Critical Survey of the Brittle Failure in Carbon Plate Steel Structures Other than Ships, M. E. Shank. Interest of the Army in Brittle Failures, T. T. Paul. Theory of Brittle Fracture and Criteria for Behavior at Low Temperatures, E. R. Parker. Brittle Fracture, S. L. Hoyt. Metallurgical Aspects of Low-Temperature Behavior in Ferrous Materials, C. H. Lorig. Fundamentals of Fractures in Metals, M. Gensamer. The Effect of Size upon Fracturing, G. R. Irwin. Brittleness, Triaxiality, and Localization, W. P. Roop. Effect of Metallurgical Structures on the Impact Properties of Steels, J. A. Rinebolt. Evaluation of the Significance of Charpy Tests, William S. Pellini. Significance of V-Notch Impact Test in Evaluation of Armor Plate, A. Hurlich. Notch Bend Tests for Evaluating the Properties of Weldments, R. D. Stout. Reproducibility of Keyhole Charpy and Tear-Test Data on Laboratory Heats of Semiskilled Steels, R. H. Frazier, J. W. Spretnak, and F. W. Boulger. Effect of Specimen Preparation on Notch-Toughness Behavior of Keyhole Charpy Specimens in the Transition Temperature Zone, R. W. Vanderbeck, R. W. Lindsay, H. D. Wilde, W. T. Lankford, and S. C. Synder. Low-Temperature Impact Properties of Titanium, David E. Driscoll. Effects of Boron on the Impact Properties of Quenched and Tempered Steels, H. Schwartzbart and J. P. Sheehan. The Notched-Bar Impact Properties of Tempered Martensite in Medium Carbon, Medium Alloy Grades of Steel, M. Baeyertz, W. F. Craig, Jr., and J. P. Sheehan. Notch Sensitivity of Steels, E. J. Ripling. Effect of Carbon and Nitrogen on the Tensile Deformation of High-Purity Iron at 81°F (27°C) and at −321°F (−196°C), Lewis D. Hall. Tension Impact Strength and Strain Distribution at Room and Sub-Zero Temperatures of Stainless and Other Steels, C. R. Mayne, V. N. Krivobok, and C. W. Muhlenbruch. Low-Temperature Toughness of Flake and Spheroidal Graphite Cast Iron, J. S. Vanick. Ductile and Brittle Failure in Ferritic Nodular Irons (Nickel-Magnesium Type), G. N. J. Gilbert. The Low-Temperature Properties of Cast Irons, G. N. J. Gilbert. Impact Properties of Ferritic Ductile Iron, R. W. Kraft.

METEOROLOGY

Man and the Winds. E. Aubert de la Rue. New York, Philosophical Library, 1955. 206 pp., illus. $6.00.

A survey of winds as they affect man in agriculture and forestry, building and town-planning, sociology and engineering, biology and medicine, travel and sport. Though it would appear to be of fundamental interest to the meteorologist, the nontechnical treatment and historic information give this "geographical wind-atlas" a broader base of appeal.

PHYSICS

Modern Physics; A Textbook for Engineers. Robert L. Sproull. New York, John Wiley & Sons, Inc., 1956. 491 pp., illus., diagrs., tables. $7.75.

The author, Associate Professor of Physics at Cornell University, has developed this book from notes used in a course for engineering undergraduates and in courses for practical engineers at Westinghouse, Corning Glass, and Sylvania. The approach is analytical rather than only descriptive. The crucial experiments are analyzed and the elemental theory underlying the properties of atoms, molecules, solids, and nuclei is based on this analysis. The analysis is carried far enough so that the "new" physics can be applied to understanding processes (such as thermionic emission or the nuclear reactor), instruments (such as the optical pyrometer or the mass spectrometer), and the properties of materials (such as ferromagnetic materials or semiconductors). For self-study or for formal program, features include a large number of problems with a wide range of difficulty and a good selection of references at the end of each chapter. M.k.s. units are employed throughout. One of the several appendices give simple instructions for converting to c.g.s. units.

POWER PLANTS

Gas Turbine Principles and Practice. Sir Harold Roxbee Cox, Ed. Written by 24 Specialist Contributors. New York, D. Van Nostrand Company, Inc., 1955. 948 pp., illus., diagrs., tables. $17.50.

Divided into 30 sections, all under the editorship of the former Managing Director of Power Jets (Research and Development) Ltd., and written by specialists, this volume (which gives indication of future editions) is intended for engineers and designers in aeronautical, marine, industrial, transport, and allied spheres, and for third-year and postgraduate students. The Editor is now Vice-Chairman of the College of Aeronautics, Cranfield. Each section is rounded off with a bibliography. The arrangement of material, the over 600 illustrations, and the 93 tables give the book the added feature of a desk reference volume.

Contents. (1) Introduction, Sir Harold Roxbee Cox. (2) Gas Turbine Cycles, R. E. Wigg. (3) Thermodynamics, E. Glaister and A. G. Smith. (4) Mechanical Aspects of Gas Turbine Design, G. B. R. Feilden. (5) The Axial Compressor, A. D. S. Carter. (6) Centrifugal Compressors, L. J. Cheshire. (7) Positive Displacement Compressors, J. Shapiro. (8) Axial Turbines, L. J. Cheshire. (9) The Radial Turbine, A. W. H. Jamieson. (10) Materials of Construction, C. G. Conway. (11) Steady Stresses in Turbine Com-

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PRODUCTION

Engineering Drawing and Geometry. Randolph P. Hoelscher and Clifford H. Springer. New York, John Wiley & Sons, Inc., 1956. 510 pp., illus., diagrs. $8.00.

The authors, both professors of general engineering at the University of Illinois, present an entirely rewritten version of "Engineering Drawing" (published 1935), by Harvey H. Jordan and R. P. Hoelscher. Designed for engineers and students employing the organization and methods of the previous book, the stress is on engineering rather than descriptive geometry. Among the special features are: Axonometric projection as well as standard isometric and oblique; up-to-date material on design for interchangeable assembly, covering limit dimensioning, geometrical, and positional tolerancing; an appendix containing tables needed in the drafting room; and problem material—enough for four semesters without repetition. Workbooks designed for use with text are available.

ROTATING WING AIRCRAFT

Proceedings of the Second Annual Western Forum, September 21 and 22, 1955, Los Angeles. New York, American Helicopter Society, Inc., September, 1955. 171 pp., illus. $5.50; $3.50 to AHS Members. (*Corrected title of annotation appearing in the January issue, p. 150.*)

THERMODYNAMICS

The Chemical Kinetics of Excited States. Keith J. Laidler. Oxford, The Clarendon Press; New York, Oxford University Press, 1955. 180 pp., diagrs., tables. $4.80.

A theoretical treatment of the chemical kinetics of reactions that involve electronically excited species, either as reactants or as products. Subject matter is closely related to the fields of photochemistry, radiation chemistry, and combustion kinetics. The book is mainly concerned with giving a uniform discussion of the basic theoretical material that is common to these fields. Though theoretical in approach, considerable use has been made of experimental material, in particular of kinetic and spectroscopic data. Attention is drawn to Chapter 8 which deals with the kinetics of reactions occurring in flames. The author (Associate Professor of Chemistry at the Catholic University of America) presupposes a general knowledge of elementary quantum mechanics, spectroscopy, and chemical kinetics on the part of his advanced reader. Bibliography is scattered

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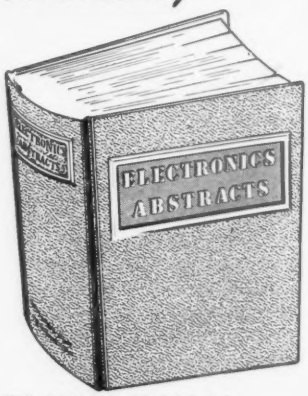

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throughout in the form of footnotes. Use of the material is facilitated by Name and Subject Indexes.

Temperature: Its Measurement and Control in Science and Industry, Vol. 2. Hugh C. Wolfe, Ed. Papers presented at the Third Symposium on Temperature, Washington, October 28–30, 1954. Sponsored by American Institute of Physics; National Bureau of Standards; and Office of Ordnance Research, U.S. Army. New York, Reinhold Publishing Corporation, 1955. 467 pp., illus., diagrs., tables. $12.

This volume contains all the papers presented at the Symposium with the exceptions of "Temperature in Relation to Flow Processes," by J. G. Kirkwood, and "Temperature in Shock Waves," by A. R. Kantrowitz.

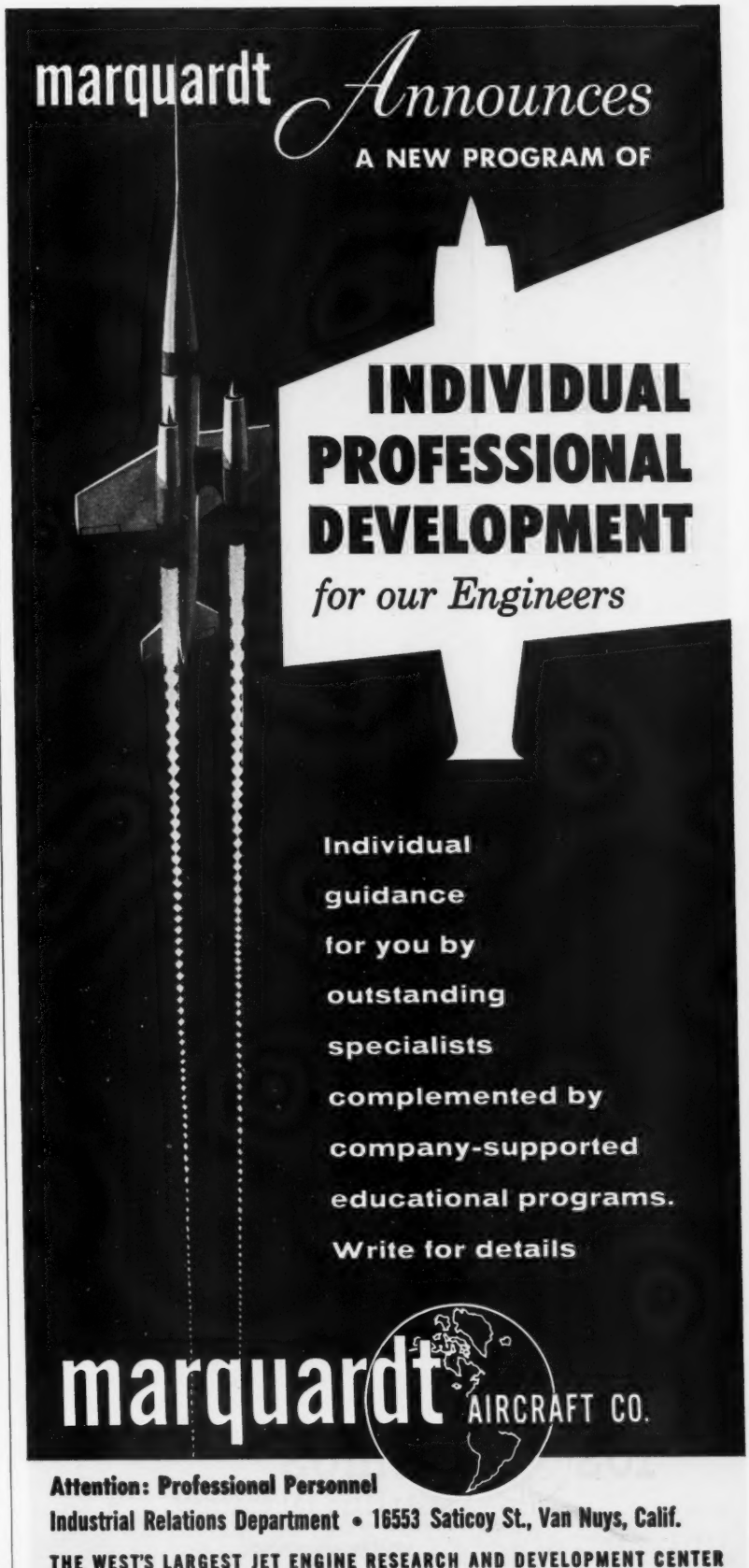
Contents: The Temperature Concept, Hugh C. Wolfe. The Concept of Temperature Near Absolute Zero, F. E. Simon. High Gas Temperatures, G. H. Dieke. Astrophysical Temperatures, Cecilia Payne-Gaposchkin. Gas Thermometry, James A. Beattie. Thermodynamic Temperatures Obtained from P-V Isotherms of He Gas between 2° and 4°K, William E. Keller. High Temperature Gas Thermometry, Helmut Moser. The International Temperature Scale, J. A. Hall. Precision Resistance Thermometry and Fixed Points, H. F. Stimson. The Zinc Point as a Thermometric Fixed Point, H Preston-Thomas. Low Temperature Scales from 90° to 5°K, R. B. Scott. The Helium Vapor-Pressure Scale of Temperature, R. P. Hudson. Techniques of Magnetic Thermometry, H. van Dijk. Thermodynamics of Irreversible Processes and Fluctuations, I. Prigogine. Relaxation of Partial Temperatures, K. F. Herzfeld. Thermometry Below 1°K, D. de Klerk. Experimental Temperature Measurements in Flames and Hot Gases, H. P. Broida. Temperature Measurement in Engineering, Harold J. Hoge. Superconductors as Thermometers, J. G. Daunt. Semiconductors as Thermometers, S. A. Friedberg. Sound Velocity as a Measurement of Gas Temperature, A. L. Hedrich and D. R. Pardue. Temperatures in Atomic Explosions, F. G. Brickwedde. Ionization Measurements at High Temperatures, W. Lochte-Holtgreven. Temperatures in the Upper Atmosphere, Homer E. Newell, Jr.

Each paper contains a bibliography and the Author Index is supplemented with a rather extensive Subject Index.

YEARBOOKS

Jahrbuch 1954 der Wissenschaftlichen Gesellschaft für Luftfahrt e.v. (WGL). Mit den Vorträgen der WGL-Tagung in Duisburg vom 13. bis 16. Oktober 1954. Herausgegeben von Hermann Blenk. Braunschweig, Friedr. Vieweg & Sohn, 1955. 324 pp., illus., diagrs., tables. DM 36. .

Contents: Georg Hamel zum Gedachtnis (George Hamel, in Memoriam), I. Szabó (Includes 83 references). Die Bedeutung der Luftfahrt für den Wiederaufbau Deutschlands (The Significance of Aviation in the Reconstruction of Germany), Leo Brandt. Transonic Wind Tunnel Development of the NACA, H. Julian Allen. Some Transonic Airflow Problems, C. H. E. Warren. Geschwindigkeitsverteilungen in zweidimensionalen gekrümmten Lavaldüsen (Velocity Distributions in Two-Dimensional Curved Laval Nozzles), Willi Jacobs. Untersuchungen an Pfeilflügeln zwischen Wänden bei schallnaher unter- und Überschallanströmung (Investigations of Swept Wings between Parallel Walls in Transonic Flow), Willi Jacobs. On the Boundary Layer with Variable Prandtl Number, E. R. Van Driest. Brachystochrone Flugbahnen im Raum bei zeitlich veränderlichem Fluggewicht (Short-Duration Flight Paths in Space with Flying Weight Varying with Time), Hermann Behrbohm. Einige Sonderfalle dynamischer Stabilität (Some Special Cases of Dynamic Stability), Karl H. Doetsch. Turbine Transports, Whither Hence? Arthur E. Raymond. Ueber die Konzeption von Coleoptern (The Concept of the Coleopter). Helmut v. Zborowski. Der Ringflügel als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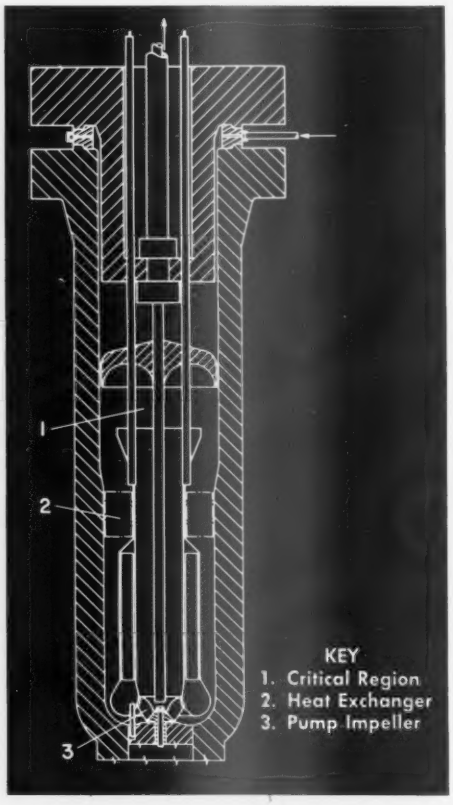

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Hubschraubern (On the Control of Helicopters), Walter Just. Zur Frage der Ermüdungsfestigkeit im Flugzeugbau (The Problem of Fatigue Strength in Aircraft Construction), E. Gassner. Entwicklungstendenzen im Strahltriebwerksbau (Development Trends in Jet Power Plants), B. Eckert. Technik der Flugsicherungsanlagen im Bundesgebiet (Air Traffic Control Techniques in Western Germany), K. Bärner. Zur Theorie der instationären Leewellen (On the Theory of Nonstationary Lee Waves), J. Zierep. Wolkenphotogrammetrie (Photogrammetry of Clouds), H. Meyer. Konvektionsströmung im flüssigen Schwefel (Convective Flow in Liquid Sulphur; Summary Only), H. v. Tippelskirch. Ein Sichtmesser für Luftfahzeuge (A Visibility Meter for Aircraft; Summary Only), G. H. Ruppersberg. Einige technische Probleme des Luftverkehrs (Some Technical Problems of Air Transportation), J. Süssenguth.

Jahrbuch 1953 der Wissenschaftlichen Gesellschaft für Luftfahrt e.v. (WGL). Mit den Vorträgen der WGL-Tagung in Göttingen vom 26. bis 29. Mai 1953. Herausgegeben von Hermann Blenk. Braunschweig, Friedr. Vieweg & Sohn, 1954. 224 pp., illus., diagrs., tables. DM 28.-.

The papers presented in this volume are as follows: Ludwig Prandtl zum Gedächtnis (Ludwig Prandtl, in Memoriam), W. Tollmien (this paper includes a 158-reference bibliography of Prandtl's works). Wege der Forschung (Ways of Research), A. Betz. Tragflächentheorie bei inkompressibler Strömung (Theory of Lifting Surfaces in Incompressible Flow), E. Truckenbrodt. The Calculation of the Profile Drag of Aerofoils and Bodies of Revolution at Supersonic Speeds, A. D. Young. Der Stand des Leewellenproblems (The Status of the Lee Wave Problem), J. Zierep. Windkanalversuche zum Studium des Flatterverhaltens eines Nurflügelflugzeuges (Wind Tunnel Tests in the Study of the Flutter Characteristics of an All-Wing Aircraft), H. Wittmeyer. Vibrations d'aubes d'un compresseur axial (Vibration of Axial Compressor Blades), S. Boudigues. Einige Bemerkungen über den Angriff des Strahltriebwerksschubes an Flugzeugzellen (Some Remarks on the Action of Jet Engine Thrust on Airframes), A. W. Quick and H. Söhngen. Der Grenzschichtzaun (The Boundary Layer Fence), W. Liebe. Étude des écoulements transsoniques; Contrôle expérimental des règles de similitude (Study of Transonic Flows; Experimental Control of the Similarity Rules), L. Malavard. Résultats concernant la structure des ondes de choc (Results of a Study of Shock Wave Structure), J. J. Bernard. Geschwindigkeit, Konstruktionsgewicht und Nutzlast moderner Verkehrsflugzeuge (Speed, Structural Weight, and Useful Load of Modern Transport Aircraft), Karl Thalau. Der Einfluss der Anfangsbedingungen auf die Entwicklung der laminaren Kompressibilen Grenzschicht in zwei Dimensionen (The Influence of Initial Conditions on the Development of the Laminar Compressible Boundary Layer in Two Dimensions), E. A. Eichelbrenner. Algemeine Probleme der Grenzschichtsteuerung (General Problems of Boundary Layer Control), G. V. Lachmann. Zur Aerodynamik der kleinen Reynolds-Zahlen (Aerodynamics at Small Reynolds Numbers), F. W. Schmitz. Erste Ergebnisse der deutschen Böenmessungen (First Results of German Gust Measurements), H Koschmieder. Zur Experimentellen Leewellenforschung (On Experimental Lee Wave Research), W. B. Klemperer. Sprödbruch von Schweissverbindungen; das Nichschmelzschweissen (Brittle Fracture of Welded Joints; Low-Temperature Welding), C. Torre. Einige Probleme bei Raketenantrieben (Some Problems of Rocket Power Plants), O. Lutz. Rückblick auf die deutschen Entwicklungen auf dem Gebiete der Funkmesstechnik (A Review of German Developments in the Field of Radar), H. Diehl. Planung und Bau von Hubschrauberflughäfen (Planning and Construction of Heliports), Werner Treibel. Ueber Stabilitätsprobleme gasförmiger Grenzschichten (On the Stability Problems of Gaseous Boundary Layers), W. Tollmien.

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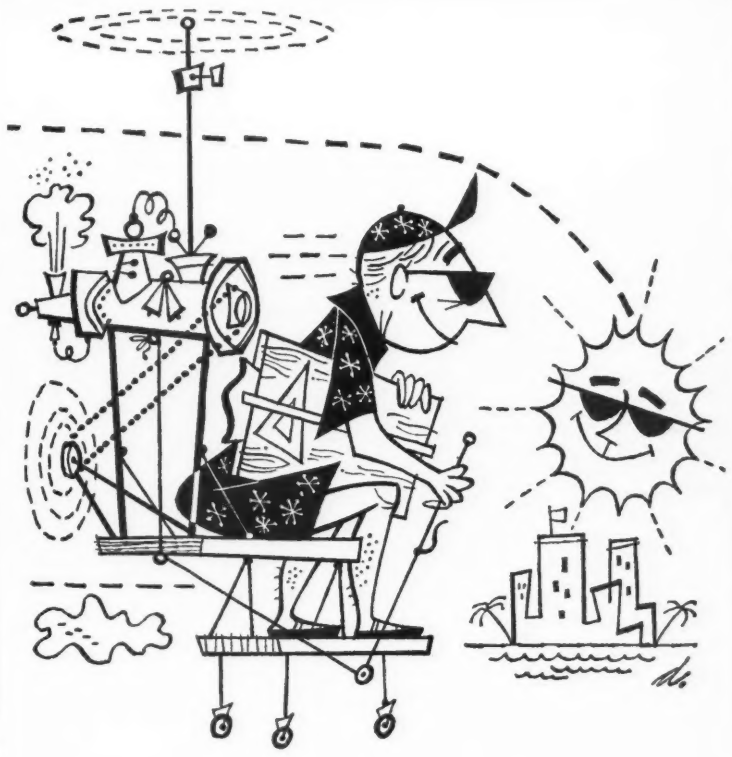

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IAS News

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Uyeda, Glen K., B.S., Jr. Engr., North American Aviation, Inc. (Downey).

Walter, William C., B.S., Proj. Engr., Bomber New Devel. Office, Bomber Branch, Weapons Systems Directorate, Detachment 1, ARDC, W-P AFB.

Yeager, Robert W., A.A. in Ae.E., Design Engr. "B," Stress Analysis, Aerojet General Corp.

Young, John H., Jr. Engr., North American Aviation, Inc. (Los Angeles).

Reviews

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L. H. Tanner. *Aero. Quart.*, Nov., 1955, pp. 241–253. Experimental calculations in incompressible flow compared to known pressures on a circular cylinder in the tunnel working section, with a description of the apparatus.

On the Theory of Two-Dimensional Wind Tunnels with Porous Walls. L. C. Woods. *Proc. Royal Soc. (London), Ser. A*, Dec. 6, 1955, pp. 74–90. Application of findings to obtain a design for zero tunnel blockage in subsonic compressible flow.

Essais en Souffierie de Maquettes Homothétiques de Flottement. R. Dat and M. Trubert. *La Recherche Aéronautique*, May-June, 1955, pp. 23–29. In French. Subsonic wind-tunnel tests to study dynamic similitude using homothetic models and taking into account wall effects and Reynolds Number modifying nonstationary aerodynamic forces.

Specifications for AGARD Wind Tunnel Calibration Models (Caractéristiques des Maquettes de l'AGARD pour l'Étalonnage des Souffieries). *NATO AGARD Memo. AG 4/M3*, Aug., 1955. 6 pp. Revised.

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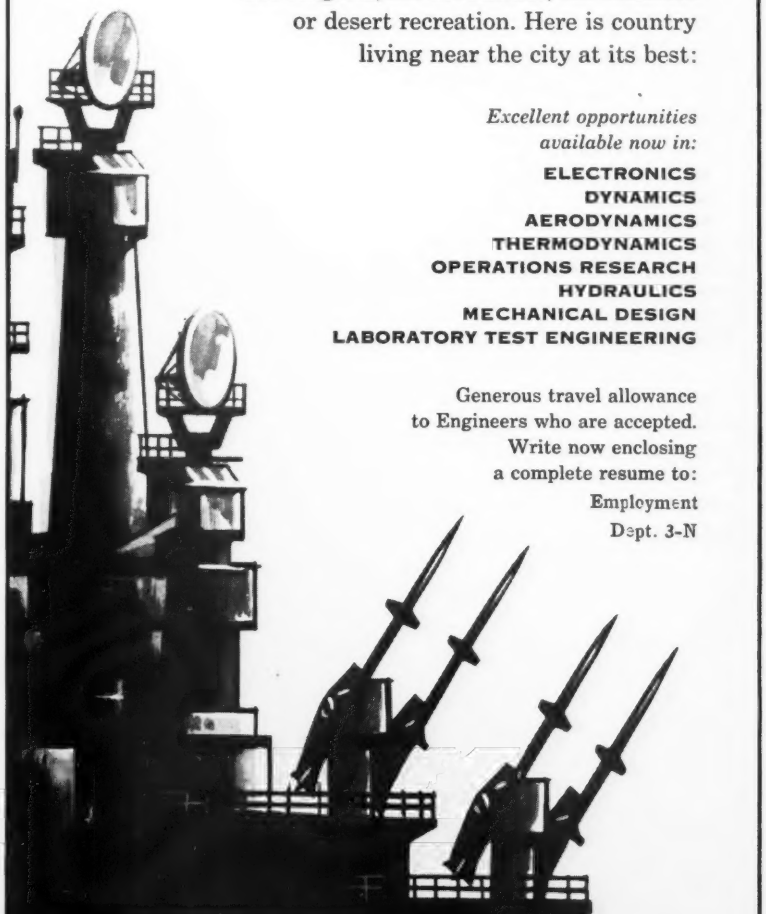

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